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ON THE STUDY OF WINGS OF POLISTES HEBRAEUS (FABR.)

By

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[Received on 5th August 1959]

The present paper deals with the studies on the wings of the common yellow wasp *Polistes hebraeus* (Fabr.). Although a considerable amount of work has been done on the morphology of the wings of different hymenopterous insects, practically nothing is known about the insect selected for the present study. Comstock and Needham plan of nomenclature has been used in describing the veins.

MATERIAL AND METHOD

The adults on wings were caught by nets, while younger stages were collected from the combs. The wings were taken out and examined both as temporary and permanent mounts. They usually curled up slightly during dehydration but for the purpose they were well spread over a slide and pressed under a cover slip while dehydrating.

OBSERVATIONS

The wasp has four membranous wings thinly clothed with fine brown setae. The wings of each side are held together by a row of hooks, the hamuli, on the front margin of the hind wing (Plate 1, fig 2 Ham); these hooks fasten to a fold in the hind margin of the front wings so that the two wings present a continuous surface beat together.

The venation is more or less reduced, much more so in the hind wing which is smaller than the fore wing. The courses of the veins specially the forked ones are very much modified; principal veins have extensively fused and their branches have a tendency to run transversely and to coalesce before reaching the wing-margin. The hind wing has an anal lobe and a very deep axillary excision and a faint preaxillary excision.

The *Costa* (Plate 1, fig. 1, C.) forms the outer margin and bears a stigma at the distal third. It is associated with humeral plate at the antero-proximal point. The humeral plate is a big flat sclerite lying between the wing and the axillaries. There does not appear any trace of *Subcosta, Radial or Medial*, which are, in fact, fused with the costa forming a stout margin. The radial manifests itself at the tip of the wing by forming a curved cord.

PLATE 1

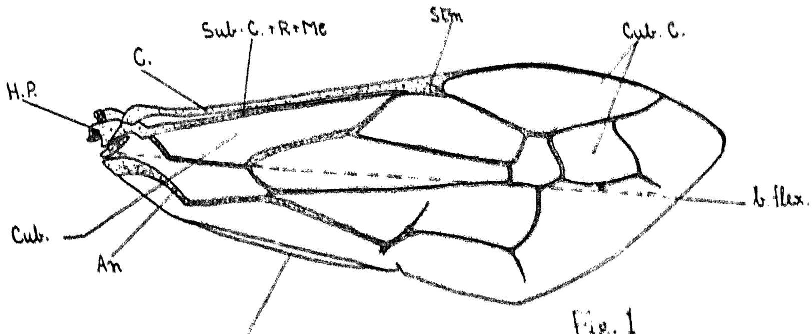

Fig. 1

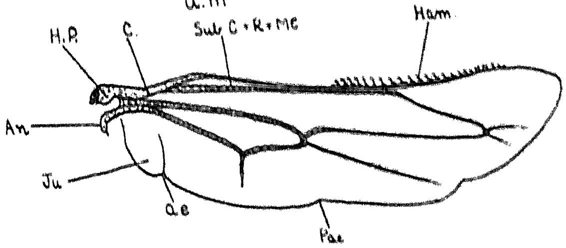

Fig. 2

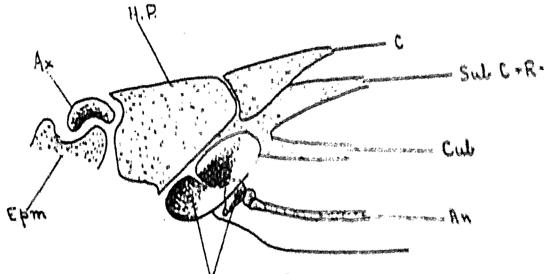

Fig. 3

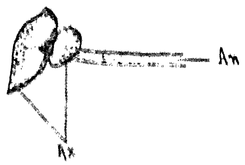

Fig. 4

Fig. 1. The fore wing with nervures.
Fig. 2. The hind wing with various nervures and hamuli.
Fig. 3. An enlarged view of the fore wing base showing the articulation with epimeron.
Fig. 4. An enlarged view of the anal nervure in articulation with the axillary.

The next vein is *cubital* (cub) which joins the stigma (stm) after enclosing a triangular median cell. It is forked at the anterior third and forms a big cubital cell just posterior to the stigma and two other smaller ones on its anterior side. The cubital gives a small branch at the proximal third, which in itself again branches. The next vein is *Anal* (an.) which meets a small branch of the cubital at the proximal third and runs forward forming two big cells anteriorly.

Articulation of wings: The wings are not directly articulated with the thorax but are interposed by a set of small chitinous pieces—the *Pteralia*, which are held together by means of an articular membrane. The shape and size of these insects depend upon the frequency and the force of the wing beats, besides the strength and the weight of the body. They are highly complicated structures in wasps. In *Vespa* wing-base sclerites have been very carefully described by Berlese and in other insects by Crampton and Stellwagg.

The Ptralia include a humeral plate (Plate I Figs. 1, 2 and 3, H. P.) at the base of the costal vein and a number of others *sclerites or* axillaries a few of which articulate with the base of the wing and others with the notal process and one lies in between. The articular region is more conspicuous in mesotergite than in the metatergite, but both are in close proximity of each other.

The proximal end of the wing is attached to a very broad and flat humeral plate on the anterior margin of the wing base and can be easily seen partly covered by the tegula in a flexed condition. The costal vein together with the median meet the humeral plate distally, the second axillary posteriorly, and the first axillary proximally. It has a deep ventral notch which plays over the latter sclerite. Close to this notch is a small ventral condyle which articulates with the fourth axillary.

The first axillary or *Alar ossicle* named as *notopterale* by Crampton, is a small curved plate like the letter 'S' placed anteriorly between the anterior wing vein, the costa and the anterior notal processes of the tergum. Its anterior ventral convex margin marked (α) articulates with a notch and the posterior ventral concave marked (β) with a convexity of the epimeron. The antero-ventral concave margin of the humeral plate, specially during the opening of wings, articulates with the dorsal convex surface of this plate marked γ (Pl. II, Fig I a.).

The second axillary (Pl. II Fig. 1 b.) is a long piece with a ventral ridge all along its length, furrowed deeply near about the middle for the insertion of muscles. Its proximal two-third is extremely black while the rest is yellowish brown. It lies obliquely meeting the cubitus at its distal end and the humeral plate on the anterior side marked (δ). The proximal portion or the ridge encloses an anterior cavity marked (γ) in which fits in a ventral carina of the humeral plate. The distal ridge has posterior cavity marked (ϕ) for articulating with the condyle of the mesoscutum. Its own proximal condylar region fits in a cavity under the notal ridge of the mesoscutum.

The next axillary is a compound sclerite formed by the fusion of a small black dorsal piece the third and a round brown ventral piece, which may be said to be the fourth (pl. II, Fig. 1, c.). The anal vein meets the dorsal piece which may be called the *Adanal pterale*. The ventral piece articulates with the posterior wing processes of the tergum and on an anterior concave face fits the convexity marked (μ) of a very complicated fifth sclerite in the middle. The third axillary is thus the posterior wing-hinge-plate of the wing base. A pair of muscles, attached to the ventral piece pull the wing, rotate it as to lie against the sides.

The fifth axillary (Pl. II, Fig. 1, e.) has a shape resembling a right angled triangle with a large number of facets all over. The hypotenuse is directed dorso-posteriorly and the dorsal apex (ω in Fig. 1, e.) meets the ventral proximal ridge of the second axillary. The facet formed by two antero-ventral processes articulates with a convexity at the posterior margin of the epimeron. The posterior apex and a part of the hypotenuse (δ in Fig. 1, e.) fits into the cavity of the fourth sclerite (μ in Fig. 1, c.) on its distal face. The rest of the margin of the hypotenuse and the proximal) area work against the sixth sclerite.

PLATE 2

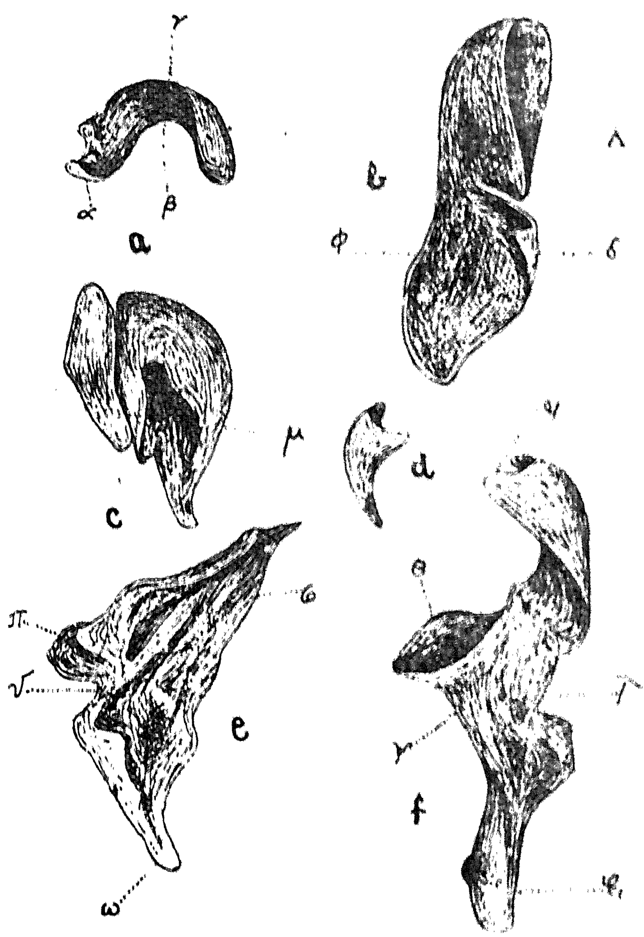

Fig. 1. Axillaries of the fore wing :
(a) First axillary.
(b) Second axillary.
(c) Third and Fourth axillary.
(d) Seventh axillary
(e) Fifth axillary.
(f) Sixth axillary.

The sixth axillary (Pl. II, Fig. 1, f.) is again a long complicated structure, the posterior half of which is black. From its anterior end arises ventrally convex arm, which at its dorsal end has two processes enclosing a facet (y) which

articulates with the ventral condyle in the middle of the proximal margin of the humeral plate. Just above the junction of this arm with the main stem there is a facet (ϕ) and the whole of the area (y) below it, works against the proximal side of the fifth sclerite. The black ventral condyle (γ) in the posterior third, articulates with a notch formed by the lateral black marginal anterior end of mesoscutellum and the posterior end of the mesoscutum. The posterior a*r*m (ξ) rests against an antero-ventral process of the mesoscutellum.

The seventh sclerite (pl. II, Fig. 1, d.) is small curved axillary generally found closely attached to the dorsal arc (ω in Fig. 1, e.) of the fifth axillary. It is a curved subtriangular str ucture convex proximally and may be supposed to be a part of the fifth axillary due to close approximation. It lies in between the fifth and sixth axillaries.

The first, second and the fourth axillaries are associated with the base of the wing and the third, sixth and seventh with the body wall while the fifth lies in between the two sets, and acts as a pivot to move the whole mechanism.

The hind pair of wings is similarly attached to the body by means of five axillaries, besides the humeral plate at the base. Actual tegula is absent but the posterolateral margins of the mesoscutellum are considerably raised into carinate ridges, which look like the tegula of the hind pair of wings.

PLATE 2

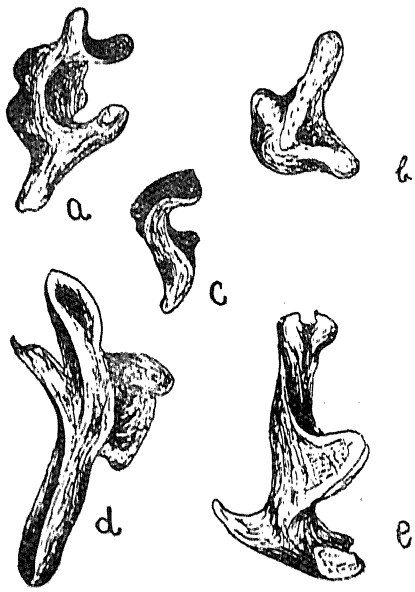

Fig. 2. Axillaries of the hind wing :
(*a*) Third axillary. (*c*) Second Axillary.
(*b*) First axillary. (*d*) Fifth axillary.
(*e*) Fourth axillary.

The first axillary (Pl. II, Fig. 2, b.) is a small tri-radiate piece with two facets articulating with the metapleuron ventrally and the humeral plate dorsally. It works exactly like the first axillary of the fore wing although the two are different in shape.

The second axillary (Pl. II, Fig. 2 c) is a small 'S' shaped piece, more than half of which is black. Into the black concavity fits ventrally the fourth axillary. Its convex margin articulates with a deep concavity in the humeral plate.

The third axillary (Pl. II, Fig. 2, a.) is more or less a sickle-shaped sclerite with the convex margin directed anteriorly; the anterior ridge of the fourth axillary fits into its posterior concavity. At the dorsal apex there is a facet to articulate with the condyle present in the middle of the wing base. The curved margin has two processes proximally, between which an arm of the first axillary fits in. There is ventral process to this curved structure which rests against the body wall.

The fourth axillary (Pl. II, Fig. 2, c.) is a long rod with two transverse processes ventrally. The lower half has a very prominent anteriorly directed round carina which fits into the posterior concavity of the third sclerite. The ventral proximal process somewhat like a condyle works against the metapleuron and the distal rests against the fifth axillary. The whole of the posterior margin is closely articulated with the anterior margin of the fifth sclerite. The dorsal end has a facet between two curved processes to articulate with black concavity of the second axillary.

The fifth axillary is an elongated piece with two lateral processes (Pl. II, Fig. 2, d.). The dorsal end and the anterior lateral margin with processes are connected with the jugum of the hind wing and with the fourth axillary on the proximal side. The ventral ends rest against the body wall.

LETTERING

ac--axillary excision of hind wing ; a. m. turned anal margin of fore wing; An--anal nervure ; Ax--axillary sclerite ; b.) flex --basal flexure ; C--costa ; Cub. cubitus ; Cub. c --cubital cell ; Epm --epimeron; Ham--hamuli; H. P.--humeral plate ; Ju--jugum; Pac--paraxillary excision of hind wing.

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ON THE VEGETATION OF KONKAN IN BOMBAY STATE

By

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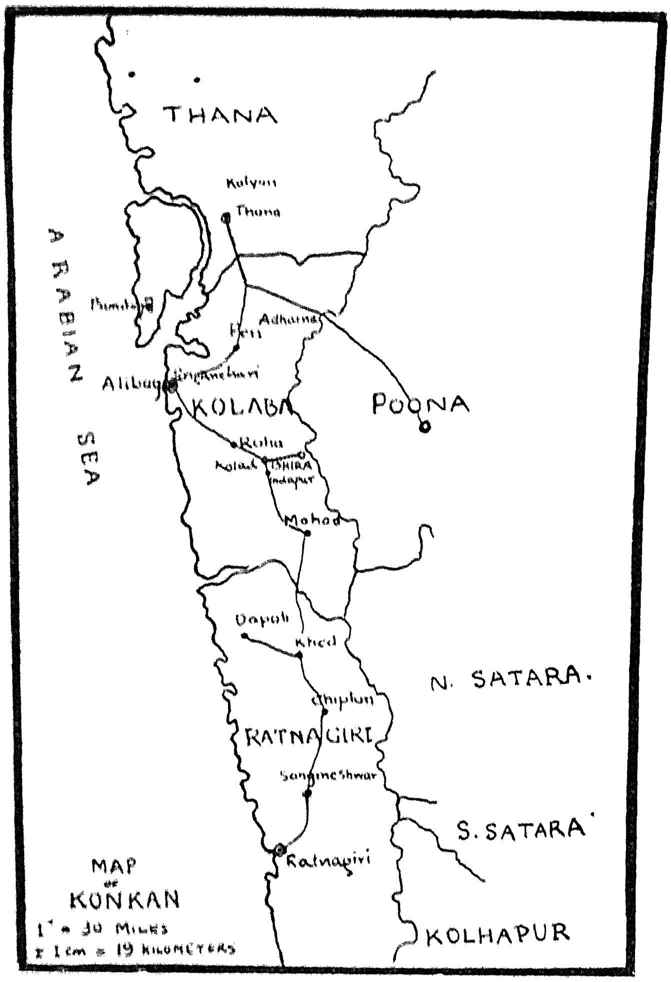
[Received on 5th May 1959]

The Konkan area in Bombay State lies approximately between latitude 17·8° to 18·40°N and longitude 72·55° E to 73·52° E. It comprises of parts of districts of Kolaba and Ratnagiri. The area of work is shown in map 1.



MAP 1

The general topography is of undulated land. Towards the coast it is plain country with frequent outcrops of lower ranges of Western Ghats. The altitude of the plain country varies from sea-level to approximately 50 m. and the hills

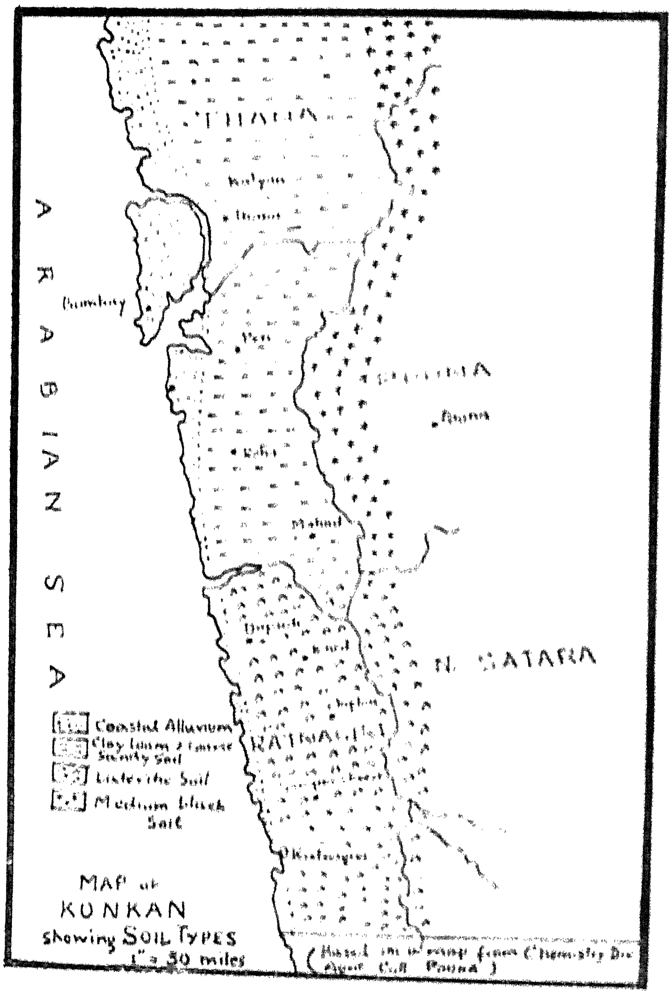
range between 100 m. to about 300 m. The hills are gradually higher and higher eastwards till they merge with the high ranges of the Western Ghats.

Almost no botanical work has been done on this area after the publication of Cooke's Flora of Bombay in 1908. No studies have at all been done on the ecological aspect of the vegetation.

Botanical collections were therefore made in different seasons of the year and the plants were identified in the Poona herbarium. Doubtful specimens were referred to the Central National Herbarium, Calcutta. After familiarizing with the flora, the vegetation was studied by means of quadrats. Transects were laid in a variety of habitats scattered all over the area.

Soils

Four main soil types are met with in the area—viz. Clayey-loam, Coarse sandy soil, Red laterite soil, and Coastal alluvium (Map 2).



MAP 2

The clayey loam soils are present in the valleys. They are greyish brown in colour and support good tree growth of moist deciduous forests, composed of *Pongamia pinnata*, *Mangifera indica*, *Syzygium cumini*, *Lagerstroemia lanceolata*, *Grewia tiliaefolia*, *Ficus glomerata*, *Terminalia* species, etc. *Vitex negundo* and *Sarcococca saligna* are common shrubs in such habitats.

Coarse sandy greyish brown soils are met with on upper slopes and hill tops of the northern half of the district and are the commonest soils of the area. They support deciduous forests. The western and north-western slopes and protected areas on such soils support moist deciduous forests. The dominant tree species on such habitats are *Tectona grandis*, *Terminalia crenulata*, *Lannea coromandelica*, *Mangifera indica* and *Garuga pinnata*. The commonest shrubs are *Carissa congesta*, *Ixora arborea*, *I. coccinea*, *Holarrhena antidysenterica*, and *Lantana camara*. Common climbers are *Cocculus hirsutus*, *Calycopteris floribunda*, *Combretum ovalifolium* and *Tinospora cordifolia*. Higher altitudes have *Carvia callosa* and *Pavetta indica* also.

The eastern and south-eastern slopes have dry deciduous type of forests. *Tectona grandis* along with *Sterculia villosa*, *Anogeissus latifolia*, *Madhuca indica*, *Butea monosperma*, *Adina cordifolia*, and *Terminalia* species are the common tree species. Shrubs of *Woodfordia fruticosa*, *Euphorbia ligularia*, and *Capparis* species grow in addition to those described above. Such vegetation was studied at Adharna, Indapur, Roha, and Ratnagiri.

The red laterite soils are present in the southern part of the district. These soils are reddish in colour, or various shades from reddish-brown to greyish-brown. These are very fertile and fine soils, and support evergreen or mixed forests. Due to heavy biotic interference, however, these habitats are also now colonized by various grades of deciduous forests. Such habitats were studied at Dapoli and Sangameshwar. Protected forests at such habitats have evergeen species such as *Garcinia indica*, *Memecylon umbellatum*, *Barringtonia acutangula*, *Terminalia chebula*, *Syzygium cumini*, *Mangifera indica*, etc.

The coastal alluvium is present all along the coast, and usually supports coconut plantations. Large areas in such habitats have been put under *Casuarina equisetifolia* plantations. In moist marshy areas mangrove vegetation is found. The mangrove vegetation was studied at Alibag, Dasgaon, and Ratnagiri.

For the study of vegetation transects were laid in all types of habitats in the area. The trees, shrubs and saplings occurring in quadrats of 5 m. radius were noted. The percentage occurrence of different species was calculated. The data obtained in these quadrat studies have been tabulated in Table I.

AREA	Adharna forest, 10 km. North-east of Pen, in Dist. Kolaba	Sriganchari forest in Alibag	Parhur, 7 km. north of Alibag	Parhur, 7 km. north of Alibag	Roha, District Kolaba
	1	2	3	4	5
ROCK AND GEOLOGY	Sahyadri range running North South	Western Ghats	Western Ghats. This hill runs NE-SW	W. Ghats	W. Ghats, range NE—SW
SOIL	Reddish brown, clayey shallow	Greyish, brown, shallow loamy	Brownish coarse	Shallow, rocky	Shallow
BIOTA	Protected & Reserved Forest	Closed forest, but illicit felling common	Closed forest but lower hill slope subject to illicit felling	Felled coupe common on this slope	Lower part of hill slope subjected to felling, middle to top protected
PARTICULARS OF QUADRATS	11 quadrats of 5 meters radius on North-western slope	11 quadrats of 5 m. radius on East slope.	10 quadrats of 5 meters on North Eastern slope	10 quadrats of 5 m. radius on South-western slope	12 quadrats of 5 meters radius on North-western slope
	Percentage	Percentage	Percentage	Percentage	Percentage
TREES:					
Acacia chundra	9	...	...	...	...
Adina cordifolia	...	...	...	...	...
Ailanthus malabarica	...	...	...	...	...
Albizzia lebbek	...	...	...	...	...
Alstonia scholaris	...	...	...	...	8
Annona reticulata	...	...	...	...	...
Anogeissus latifolia	...	...	...	...	8
Artocarpus heterophyllus	...	...	...	...	...
Bauhinia racemosa	9	...	...	20	...
Bridelia stipularis	...	...	...	30	...
Butea monosperma	9	...	...	...	...

Roha, District Kolaba	Roha, District Kolaba	Ambivali near 26 km. from Roha on Bhira line	Dasgaon Reserved forest, 8 km. North of Mahad	Dasgaon Reserved forest, 7 km. north of Mahad	Dapoli 25 km. west of Khed	Sangameshswar, Ratnagiri District	Ratnagiri near Sea creek
6	7	8	9	10	11	12	13
W. Ghats, range runs NE-SW	W. Ghats	W. Ghats, west phase	Outskirts of Western Ghats	Outskirts of W. Ghats	W. Ghats	W. Ghats	W. Ghats
Brownish shallow soil	Greyish brown soil	Grevish brown	Reddish brown soil	Reddish brown soil	Lateritic red fine soil in valley, coarse on upper slope	Reddish brown Lateritic soil in valleys, brownish on top	Reddish brown
Protected forest	Reserved forest	Reserved forest, but illicit felling seen	Subject to browsing, grazing & felling	More subject to browsing, grazing & felling	Reserved forest. Extensive browsing seen	Under shifting cultivation. Browsing heavy	Heavy felling, grazing & browsing
19 quadrats of 5 m. radius on East slope	20 quadrats of 5 m radius on western slope, middle to base	23 quadrats of 5 m. radius, random on NE & NW slope	11 quadrats of 5 meters radius on SE slope	7 quadrats of 5 m. radius on W. slope	10 quadrats of 5 m. radius on flat area	10 quadrats of 5 m. radius on Eastern slope	10 quadrats of 5 m. radius on Western slope
Percentage	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
40	...	...	...	...	...	10	...
15	...	24	...	...	...	..	...
5	...	...	—	...	...	...	...
...	...	8	...	...	...	...	...
...	...	...	...	—	...	...	...
...	...	...	9	.	...	...	...
...	20	12	...	...	...	...	...
...	...	...	...	...	...	...	20
10	...	...	9	14	...	...	...
20	...	4	36	...	20	...	10
30	10	8	27	56	—	...	...

	1	2	3	4	5
Careya arborea	...	9	—	...	8
Cassia fistula	...	...	...	...	...
Cordia dichotoma	...	...	...	...	...
Embelia tsjeriumcottam	...	...	...	...	...
Emblica officinalis	...	...	...	...	8
Erinocarpus mimmoni	...	...	...	...	...
Erythrina variegata var. orientalis	45	30	...	...	40
Ficus asperrima	...	...	...	...	...
Ficus glomerata	27	27	10	10	40
Ficus religiosa	...	...	...	...	...
Garuga pinnata	18	...	20	40	56
Gmelina arborea	...	...	...	10	...
Grewia tilaefolia	...	18	10	50	...
Heterophragma quadriculare	9	...	...	...	8
Holoptelea integrifolia	...	9	...	...	...
Lagerstroemia lanceolata	...	9	...	...	8
Lannea coromandelica	18	...	10	10	8
Madhuca indica	...	...	...	...	...
Mallotus philippensis	...	...	...	...	8
Mangifera indica	...	45	...	10	24
Memecylon umbellatum	...	...	...	...	...
Meyna laxiflora	...	9	...	...	...
Miliusa tomentosa	...	...	...	...	...
Morinda tinctoria	..	...	10	...	...
Pongamia pinnata	...	18	...	...	...
Pterocarpus marsupium	...	...	...	...	8
Randia uliginosa	...	...	...	...	...
Salmalia malabarica	18	9	10	40	32

6	7	8	9	10	11	12	13
35	...	16	27	28	...	...	...
...	5	...	...	...	...	...	...
...	5	...	9	...	...	...	..
...	...	...	9	...	...	...	...
...	...	...	...	...	...	...	...
...	...	8	...	...	...	...	...
10	35	4	27	56	...	...	...
5	...	4	...	...	...	...	...
15	30	...	...	...	...	...	...
..	5	...	...	...	...	...	...
10	50	28	9	28	...	...	...
15	...	...	...	...	10	...	10
...	...	...	18	14	...	...	30
5	...	4	...	14	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	10
35	5	12	...	...	...	10	20
...	..	20	...	...	...	...	...
5	...	...	...	...	...	...	...
10	20	4	...	...	10	30	50
...	...	...	...	...	90	...	...
10	—	8	27	28	30	20	20
10	...	...	...	...	...	...	...
10	...	...	90	56	...	...	...
...	...	...	...	...	...	...	...
5	10	...	9	28	10	...	...
5	5	4	...	...	...	...	...
25	55	40	63	42	10	20	...

	1	2	3	4	5
Santalum album	...	...	...	...	...
Sapindus laurifolius	...	...	...	...	...
Schleichera oleosa	...	...	...	...	16
Semecarpus anacardium	...	...	...	...	...
Sterculia villosa	...	...	...	30	8
Syzygium cumini	18	...	...	..	...
Tectona grandis	36	45	100	100	32
Terminalia bellerica	...	...	...	...	...
Terminalia chebula	...	...	...	...	...
Terminalia crenulata	9	...	10	20	...
Terminalia paniculata	...	...	...	...	...
Trewia polycarpa	...	...	...	...	16
Wrightia tinctoria	9	9	...	...	...
Xylia dolabriformis	18	9	...	...	8
Zizyphus oenoplia	...	...	...	10	16
Zizyphus rugosa	9	18	...	...	8
SHRUBS AND CLIMBERS					
Abrus precatorius	...	...	20	10	...
Acacia intsia	...	...	10	...	8
Aloe sp.	...	...	...	...	...
Anacardium occidentale	...	...	...	...	...
Atalantia racemosa	...	...	...	10	...
Bambusa bambos	9	...	...	...	...
Butea superba	...	...	...	...	...
Calycopteris floribunda	9	...	30	40	24
Capparis spinosa	18	18	20	40	8
Carrissa congesta	81	45	90	80	80
Carvia callosa	...	27	...	...	16
Casearia graveolens	...	...	...	...	8

1—(*Continued*)

6	7	8	9	10	11	12	13
...	...	...	...	...	10	...	...
...	...	...	...	...	10	...	...
...	..	4	...	...	...	...	...
...	5	...	...	...	...	...	...
...	10	...	...	...	...	...	20
...	...	16	...	...	30	...	...
20	65	...	18	56	80	...	...
25	...	16	...	...	20	20	...
...	...	...	...	...	10	...	...
15	15	68	...	56	...	10	...
30	...	20	72	42	...	60	...
...	25	...	54	28	...	...	...
...	...	12	...	...	...	...	...
20	...	...	...	...	...	...	...
...	10	12	...	42	10	30	...
25	...	4	27	56	40	40	...
..	...	...	27	...	...	...	...
15	5	4	...	...	20	...	...
...	...	...	36	14	...	...	...
...	...	...	9	...	20	..	20
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	12	...	...	...	30	...
40	45	40	27	42	...	50	...
...	...	...	48	...	...	...	...
60	55	76	100	42	60	80	...
...	...	...	...	...	...	...	...
5	40	4	...	...	10	...	...

TABLE

	1	2	3	4	5
Cissus sp.	...	9	30	30	16
Celastrus paniculatus	9	...	...	...	...
Cocculus hirsutus	...	...	40	...	...
Colebrookia oppositifolia	...	...	...	...	32
Cissampelos pareira	...	...	...	...	...
Combretum ovalifolium	9	...	...	...	...
Cryptostegia grandiflora	...	...	10	...	...
Dalbergia sympathetica	...	...	...	...	...
Dioscorea sp.	18	...	...	...	...
Euphorbia ligularia	...	9	30	50	8
Flacourtia indica	18	...	20	...	...
Gardenia gummifera	...	...	...	10	...
Helicteres isora	...	...	...	10	...
Hemidesmus indicus	...	9	...	...	...
Holarrhena antidysenterica	...	...	10	...	...
Ipomea soluta	...	...	...	...	...
Ixora coccinea	...	...	10	...	...
Ixora arborea	...	18	50	50	...
Jasminum malabaricum	9	...	50	90	...
Jatropha curcas	...	...	...	...	16
Lantana camara	9	18	...	...	24
Leea macrophylla	...	9	...	...	...
Pavetta indica	...	...	70	20	40
Pogostemon parviflorus	...	...	...	20	...
Rauvolfia serpentina	...	...	...	...	...
Securinega leucopyrus	...	...	...	...	...
Smilax zeylanica	...	...	10	...	24

6	7	8	9	10	11	12	13
...	5	...	18	42	10	20	...
...	...	...	...	...	...	...	...
...	...	...	...	14	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	20	...	...
...	5	...	45	42	...	...	...
...	...	...	...	...	...	...	...
...	...	...	100	56	...	...	...
...	5	...	...	...	...	10	...
...	10	...	72	14	10	...	10
...	5	8	...	56	20	...	...
...	...	8	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	10	...
45	55	44	81	56	50	80	...
...	5	...	9	...	...	...	...
...	...	84	...	...	20	...	...
10	45	...	9	...	10	...	...
5	...	16	100	100	40	20	...
...	...	...	...	...	...	...	...
...	10	...	9	28	...	...	...
...	5	...	18	14	...	30	...
5	35	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	10	...
...	...	...	...	...	10	20	...
5	10	28	10	28	20	...	...

	1	2	3	4	5
Tinospora cordifolia	18	...	10	...	...
Wagatea spicata	...	...	...	...	...
Woodfordia fruticosa	...	...	30	...	...
SAPLINGS OR HERBS					
Acacia chundra	9	...	...	...	...
Adina cordifolia	...	...	...	...	...
Bridelia stipularis	...	...	...	...	16
Butea monosperma	...	...	...	...	...
Careya arborea	...	...	10	...	...
Caryota urens	...	...	...	...	...
Cassia fistula	...	9	...	...	...
Diospyros melanoxylon	9	...	...	...	...
Heterophragma quadriculare	...	...	10	...	...
Lagerstroemia lanceolata	...	...	...	...	...
Lannea coromandelica	...	...	...	...	...
Memecylon umbellatum	...	...	...	...	...
Mitragyna parvifolia	...	...	...	10	...
Pongamia pinnata	...	9	...	...	...
Syzygium cumini	...	9	...	...	...
Tectona grandis	...	...	...	...	...
Terminalia chebula	...	...	...	...	...
Terminalia crenulata	...	...	...	...	...
Terminalia paniculata	...	...	...	...	...
Trewia nudiflora	...	...	...	...	...
Wrightia tinctoria	...	...	10	...	...

I—(*Concluded*)

6	7	8	9	10	11	12	13
...	...	...	...	...	10	...	...
15	5	8	...	...	...	...	...
...	...	...	72	28	...	...	...
...	...	...	...	...	...	...	...
...	...	...	14	...	...	...	...
...	...	...	...	...	...	20	...
...	...	4	...	...	...	...	...
...	20	4	...	...	...	10	...
...	...	...	...	...	10	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	4	...	...	10	...	...
...	...	8	...	...	...	20	...
...	...	...	...	...	50	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	5	...	...	...	...	...	...
...	...	...	...	...	20	...	...
...	5	8	...	...	...	...	...
...	10	...	...	...	10	50	...
...	...	4	...	...	...	...	...
...	...	...	...	...	...	...	...

The main features of the vegetation of the various places studied are described below.

Adharna Forest

This forest is situated about 10 kilometers north-east of Pen in Kolaba district, The western and north-western slopes have denser vegetation. The top is 'malki' land and has been subjected to felling. The south-east slope has poorer vegetation. The forest is predominantly of mixed deciduous type, composed of *Tectona grandis-Erythrina variegata* var. *orientalis* community. Other common trees in the community are *Ficus glomerata, Terminalia crenulata, Garuga pinnata, Lannea coromandelica, Salmalia malabarica, Syzygium cuminii, Xylia dolabriformis*. The trees in the second storey are *Acacia chundra, Bauhinia racemosa, Butea monosperma, Wrightia tinctoria* and *Zizyphus rugosa.*

The shrub layer consists chiefly of *Carissa congesta, Capparis* sp., *Lantana camara* and *Flacourtia indica. Tinospora cordifolia, Calycopteris floribunda* and *Jasminum malabaricum* are commonest climbers in the area.

Clumps of *Euphorbia ligularia* and *Jatropha curcas* are common near habitation and along agricultural fields.

Sriganchari Forest

This forest is situated near Alibag. The forest is closed to felling, grazing etc., but illicit felling and lopping is common. The forest is chiefly of mixed deciduous type but patches of moist deciduous and dry deciduous type are also seen. Wherever forest fires or felling have cleared the area the forest department are planting teak. Thus, though economically more valuable, the forest is facing retrogression from moist or mixed forest to deciduous type. The commonest tree species are *Tectona grandis, Mangifera indica, Pongamia pinnata, Grewia tiliaefolia* and *Ficus glomerata*. Trees of *Garuga pinnata, Lannea coromandelica, Erythrina variegata, Syzygium cumini, Terminalia bellerica* and *Careya arborea* also occur. The common shrubs in this forest are *Carissa congesta, Zizyphus rugosa, Lantana camara, Ixora arborea, Capparis spinosa. Carvia callosa* is common on upper slopes. *Jasminum malabaricum, Tinospora cordifolia, Calycopteris floribunda, Cocculus hirsutus* and *Dioscorea* speci s are common climbers. *Combretum ovalifolium* is frequently met with on the outskirts of the forest.

Parur and Karla forests about seven kilometers in north-east of Alibag have almost similar vegetation, Teak is abundant here. Other trees are same as at Sriganchari. The shrub layer is rather dense and is composed of *Abrus precatorius, Cissus* sp., *Cryptostegia grandiflora, Flacourtia indica, Pavetta indica, Smilax zeylanica* and *Woodfordia fruticosa,* in addition to the species which were common at Sriganchari. The ground flora here showed frequent regeneration of *Careya arborea, Wrightia tinctoria,* etc. The south-western slopes of these hills have denser vegetation and trees of *Bridelia stipularis, Bauhinia racemosa, Gmelina arborea, Sterculia villosa* and *Terminalia* spp., are also seen here.

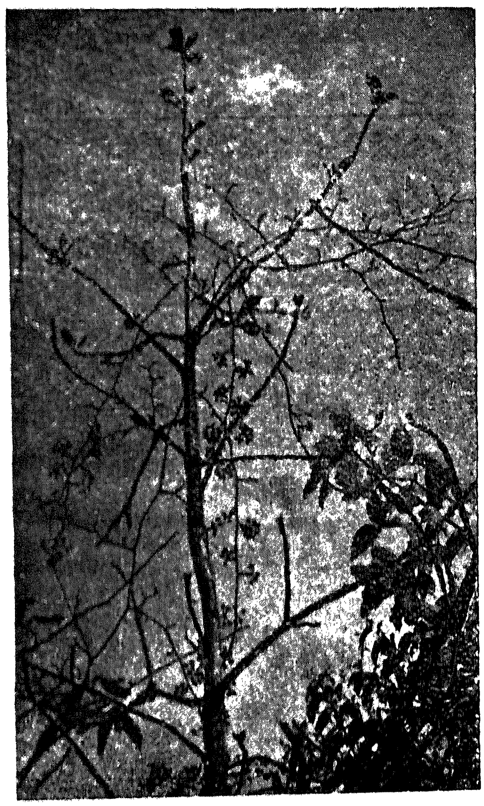
Roha

The forests of Roha are situated near the town of Roha. The different slopes of the hills were studied. The forests are closed to grazing by the Forest Department, but the lower slopes nearer to habitation are subjected to illicit felling and lopping.

PLATE I

Ph. 1 *Garuga pinnata*, a common tree in the deciduous forests at Adharna.
(Photo : Jain)

Ph. 2. *Smilax zeylanica* climbing on trees of *Tectona grandis*. A shrub of *Zizyphus xylopyra* seen on right. [illegible] bari Forest, [illegible].
(Photo : Jain)

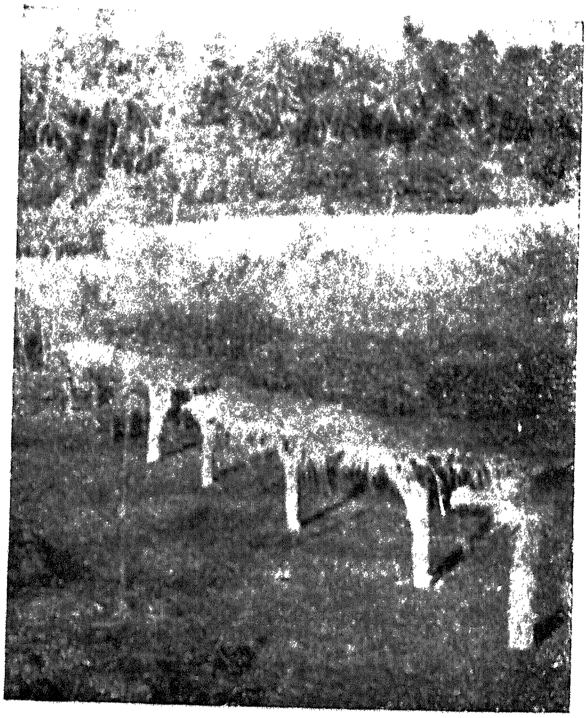


Ph. 3. A moist deciduous forest at Alibag. Large tree of *Lannea coromandelica* with robust climber *Tinospora cordifolia*. Dense shrubs of *Carissa congesta* on right.

(Photo : Jain)

Ph. 4 Forest nursery near *Casuarina equisetifolia* plantations at Nagaon. Coconut plantations in background.

(Photo : Jain)



The lower parts of the norh-eastern slope have trees of *Tectona grandis*, *Mangifera indica*, *Ficus glomerata*, *Garuga pinnata*, *Lannea coromandelica*, *Erythrina variegata* var. *orientalis* and *Salmalia malabarica*. The shrub layer consists of *Carissa congesta*, *Trewia nudiflora* saplings, *Zizyphus oenoplia*, *Z. rugosa*, and *Holarrhena antidysenterica*. The upper parts of this slope have many trees of *Anogeissus latifolia*, at places almost in pure crop. The top of the hill has *Anogeissus latifolia* mixed with *Sterculia villosa*, *Garuga*, teak, etc. An adjacent hill has denser vegetation and trees of *Acacia chundra*, *Ailanthus malabarica*, *Careya arborea*, *Butea monosperma*, *Terminalia bellerica* and *T. crenulata* are present along with the species describ d above. The vegetation on the western slope is denser still, and trees of *Erythrina*, *Salmalia*, *Sterculia*, *Ficus* and *Garuga* are very common. The shrub layer is composed of *Holarrhena antidysenterica*, *Garvia callosa*, and *Carissa congesta* and species of *Ixora*.

Bhira

The location of Bhira is interesting. It is situated on the western foot of erect high wall of Sahyadaris On way from Roha to Bhira the trolly line runs along the river Kundlika. Trees of *Lagerstroemia lanceolata*, *Mangifera indica*, *Salmalia malabarica*, *Pongamia pinnata*, *Ficus glomerata*, *Cordia dichotoma*, and shrubs of *Zizyphus rugosa*, *Randia uliginosa*, *Vitex negundo* and *Sarcococca saligna* are abundant all along the tract.

The vegetation was studied at Ambivli 11 kilometers west of Bhira. The forest is predominantly of *Terminalia crenulata*. Trees of *Adina cordifolia*, *Anogeissus latifolia*, *Careya arborea*, *Garuga pinnata*, *Madhuca indica*, *Salmalia malabarica*, *Syzygium cumini*, *Terminalia bellerica* and *T. paniculata* are also commonly met. The shrub layer is composed mainly of *Carissa congesta*, *Ixora coccinea*, *Calycopteris floribunda*, *Holarrhena antidysenterica* and saplings of *Lagerstroemia* and *Terminalia*. Freshly exposed surfaces of amygdaloidal soils have dense growth of *Woodfordia fruticosa*.

Kolad

The Subeli forest, 8 kilometers north of Kolad town was studied. It is a mixed deciduous type of forest. The dominant community is *Mangifera indica*—*Tectona grandis* community. Other common trees in the forest are *Meyna laxiflora*, *Heterophragma quadriloculare*, *Terminalia crenulata*, *Cassia fistula*, *Grewia tilaefolia Careya arborea*, *Adina cordifolia*, *Madhuca indica*, *Erythrina variegata* var. *orientalis*, etc. The commonest shrubs are *Casearia graveolens*, *Flacourtia indica*, *Zizyphus oenoplia*, *Holarrhena antidysenterica* and *Carissa congesta*, There are a number of robust climbers in the forest including *Gnetum ula* which is very conspicuous.

Nagorli Forest

Indapur—The forest here is of dry deciduous type composed chiefly of Teak, *Garuga pinnata*, *Lannea coromandelica*, *Erythrina variegata* var. *orientalis*, *Terminalia*, *crenulata*, *Salmalia malabarica*, *Anogeissus latifolia*, *Meyna laxiflora* and *Lagerstroemia lanceolata*. The forest is subject to considerable damage by biotic interference and trees are rather sparse and malformed.

Mahad

The teak forests of Mahad were studied. There is teak plantation and trees of *Acacia arabica*, *Zizyphus mauritiana* grow mixed in the teak plantations.

About 7 kilometers north of Mahad is the Dasgaon Forest. The soil is reddish brown. The lower parts of the hills have scrub vegetation and commonest scrubs here are *Holarrhena antidysenterica, Woodfordia fruticosa, Carissa congesta, Lantana camara, Euphorbia ligularia* and saplings of *Trewia nudiflora. Jasminum malabaricum* and *Dalbergia sympathetica* are very common climbers. One single plant of *Rauvolfia serpentina* was seen in flower in the month of May. Trees of *Salmalia malabarica, Trewia polycarpa, Terminalia crenulata, T. paniculata, Garuga pinnata,* Teak, *Bridelia squamosa, Careya arborea, Butea monosperma, Erythrina, Grewia tiliaefolia, Meyna laxiflora, Pterocarpus marsupium* and *Morinda tinctoria* are commoner near the top.

Mangrove vegetation was studied in a sea creek backwater near Dasgaon. Shrubs of *Aegiceras corniculatus* and *Acanthus ilicifolius* are very common here.

Dapoli

This place is situated 25 kilometers west of Khed on the Mahad—Ratnagiri Road. The soil is fine red laterite in lower valleys and coarse greyish brown on upper slopes and hill tops.

The reserved forests in valleys are of mixed deciduous type tending towards evergreen. The presence of *Garcinia indica, Memecylon umbellatum, Syzygium* species and dominance of *Terminalia* species, namely *T. bellerica, T. crenulata, T. chebula,* and *T. paniculata* are suggestive of the evergreen nature of the forests. Trees of *Barringtonia acutangula* were seen along the river Jog.

The hill slopes have less reddish, rather brownish coarse soil. They support forests of the moist or dry deciduous type as described for the various localities above. The hill-tops have dry deciduous forests.

Sangameshwar

This is situated on main West—coast road, 40 kilometers north of Ratnagiri. The present vegetation is the remnant of one-time almost evergreen vegetation. Heavy cutting and browsing has been done, and all possible areas have been brought under cultivation. Signs of shifting cultivation are evident. Slopes where cultivation is not possible have tree growth. Commonest trees are *Terminalia crenulata T. paniculata, T. bellerica, T. chebula* and *Mangifera indica.* Trees of *Garcinia indica, Macaranga peltata* and *Ficus* species are also seen.

Halarrhena antidysenterica and *Claycopteris floribunda* are very abundant shrubs all over, along with the other commoner shrub species such as *Carissa, Lantana, Zizyphus* etc. Species of *Jasminum, Dioscorea, Smilax, Combretum, Cissampelos* and *Cissus* are common climbers. *Rauvolfia serpentina* plants were seen growing wild at few places, usually singly and under the bushes of *Holarrhena* and *Calycopteris.*

The study of the vegetation of these various spots indicates that the plant communities in the area are edaphic or bio-edaphic. Good fertile soil and good rainfall warrant a dense vegetation cover on all hills and alluvial plains of the Konkan. With exclusion or control of biotic interferences in the area, the forests of the district will gradually tend towards mixed evergreen or even evergreen stage.

The economic aspect of the vegetation was studied. The forests have valuable timber species such as teak, Terminalias, mango, *Pterocarpus marsupium, Grewia tilaefolia, Anogeissus latifolia, Garuga pinnata, Lannea coromandelica* etc. Teak

is being vigorously protected and expanded by Forest Department. *Salmalia malabarica* is a well-known match-wood tree, common in the area. A large number of medicinal plants grow abdundant e. g. *Holarrhena antidysenterica, Tinospora cordifolia, Terminalias, Abrus precatorius, Celastrus paniculatus, Helicteres isora, Hemidesmus indicus, Smilax zeylanica* etc, *Rauwolfia serpentina* plants were seen growing wild at Sangemeshwar and Dasgaon. They were too few to be suggested for any commercial exploitation. The data, however, indicates the suitability of these localities for its cultivation and extension.

The studies are being continued further for fuller knowledge of the flora, its successional trends and economic exploitation of the vegetable wealth of this area.

I am grateful to Dr. G. S. Puri, Regional Botanist, and Dr. J. C. Sen Gupta, Chief Botanist B. S. I., for their kind help and facilities in these studies. Thanks are due to the Chief Conservator of Forests, Bombay, and his officers in Konkan for their help in field work.

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THE ROOT SYSTEMS OF *TEPHROSIA PURPUREA* PERS. AND *ACANTHOSPERMUM HISPIDUM* DC. IN DIFFERENT SOIL TYPES OF JABALPUR

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INTRODUCTION

A desirable type of root system is one that fully occupies the soil to an adequate depth with sufficient radius to secure enough water and nutrients in order to promote good growth at all times (Weaver, 1925). Roots have been demonstrated to have four separate physiological and morphological functions (cf. Esau, 1953; Russel, 1953; and Eames and MacDaniels, 1947). Recently, Mothes (1958) has shown that root appears to have an important role in the carbohydrate metabolism of plants. According to him the carbohydrate metabolism is not completed in absence of roots.

Our knowledge of interactions between soil, root and neighbouring root system is very scanty. Some of the outstanding work on the root systems of crop plants, grasses and herbs is due to Weaver and his co-workers (cf. Weaver, 1915, 20 & 25; Weaver, Kramer & Reed, 1924; Weaver and Bruner, 1927 and Weaver and Clements, 1938). They have shown that the form of root system of a given species depends largely upon the prevailing edaphic conditions, such as water content, pore space, texture of the soil, etc. Similar observations have been made by Biswell (1935), Brenchley and Jackson (1921), Haasis (1921), Holch (1931) and Muller (1946). In heath plants according to Heath and Luckwill (1938), the peat habitat al may even replace the tap root system to an adventitious one. Cannon (1911, 24 & 25), Convay (1940), Dean (1933), Elliot (1924), Noyes, Jrost and Voder (1918), Kramer (1949) and Russel (1953) have shown that the manner in which a root system develops depends both on its heriditary potentialities and such environmental factors as soil texture, moisture, aeration and temperature, etc. The interspecific competition between roots may as well effect in their development (Weaver & Clements, 1938; Pavlychenko, 1937; Cole & Holch, 1941 and Russel, 1953).

In India, Pandeya (1953) has shown that the root system of *Bothriochloa pertusa* (Linn. A. Camus.) is less developed under grazed conditions. Shanti Sarup and Tandon (1955) have correlated the root systems of *Gynandropsis pentaphylla* with the nature of soil and its water content. Root systems of *Euphorbia hirta*, *Russellia tuberosa* and *Phyllanthus niruri* have been studied by Ambasht (1957) in relation to the physiographic factors. Recently Joshi and Kambhoj (1959) have described the root system of *Giseckia pharnaceoides* Linn. In very sandy localities the root system is found by them to be very long and are not deep in rocky and hard soils.

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Thus there is not much of work on the study of root systems in India. The present study was, therefore, undertaken to investigate the root systems of *Tephrosia purpurea* Pers. and *Acanthospermum hispidum* DC. as they occur in different types of soils at Jabalpur. Emphasis has been laid only on the soil physical characters.

SITUATION

The city of Jabalpur is situated at 23°3'N latitude. and 79°57' east longitude. It makes a rocky basin about 393·5 meters above sea level, and is surrounded by granitic hills which are not more than 488 meters from sea level. The highest point is reached near Sidh Baba temple in the north and is about 519·5 meters high. The city lies 6 miles north of the river Narmada. It has carved out high cliffs. The famous Marble Rocks on either banks of the river (about 12 miles from the town) have been exposed by this river only.

CLIMATE

The climate of Jabalpur is salubrius. The rainfall ordinarily exceeds 1,352 m.m. The monsoon months are June to early September when about 1,125 mm. of rainfall is obtained; July and August are the wettest months. The mean maximum temperature during the period is 32·7°C and the mean minimum is 23·7°C. This is followed by winters lasting for about 4 months when the days are cool and bright with moderate intensity of wind from the west. The rainfall during this. period seldom exceeds 60 m.m. The mean maximum and minimum temperatures are 27·5° and 10·7°C, respectively. The month of March is a mild warm period of transition between cold and the following hot season, The summer extends from April to the middle of June, when the mean maximum temperature goes upto 38·5°C. However, an absolute maximum temperature of 46·6°C may sometimes be experienced in the month of May.

GEOLOGY

Jabalpur is a centre of geological interest. It is renowned for its fossil Dinosaurs and in addition one gets several outcrops of different geological formations. For the present study we shall confine ourselves to the short discription of the different soil forming rocks found at Jabalpur.

1 Calcareous Clays of Bada Simla (Lameta Hill) :

The lametas are confirmably overlain by the earliest lava flows of the deccan trap series of volcanic erruptions while it every where rests with a great uncomformity over the older rocks, whether archeans or some member of gondwans, or the bagh beds (Wadia, 1944).

The group consists of mainly chert and siliceous limestones, earthy sandstones and clays. The limestones are the most characteristic and persistent beds but are of ordinary sedimentary origin. The fine porous but earthy sandstone, usually brownish in colour, ranks second in dominance. The clays are red or green and are very frequently sandy or marly, usually of local occurrence. All these beds pass into each other. There is, as a rule, a frequent change of character in the beds, both horizontally and vertically (cf. Krishnan, 1956).

2. Sandstones :

The sandstones belong to the Jabalpur series of upper Gondwana system and are chiefly soft and massive sandstones and white or yellow shales, with some lignite or coal seams and in addition a few limestone bands (cf. Wadia, 1944).

3. Alluvium of Narmada Ravines :

The river Narmada flows in a large basin covered by extensive pleistocene and recent deposits; this is reddish brown or yellowish clay or silt with numerous bands of sand and gravel or 'kanker' (calcareous concretions) intercalated. The lowest beds are conglomerates with intercalations of grey micaceous sand and pink silts.

4. Deccan Trap (Basalt) :

The geological formation owes its origin to the enormous lava flows towards the close of cretaceous. On weathering it gives rise to black cotton soil.

5. Laterite :

At Jabalpur, low-level laterite is found mostly as capping over the deccan trap (basalt), the thickness of cappings vary. It is formed 'insitu' sub-aerial decomposition of basalt under warm, monsoonic climate.

6. Madan Mahal Granite :

At Jabalpur the outcrop is distinguished by the occurrence of perfectly dolomitic limestones at "Marble Rocks" in the river Narmada goge. Madan Mahal granite is composed of biotite-granite.

Soil Types :

The various soils derived from the aforedescribed 6 geological formations can conveniently be classified into the following two types :—

I—Residual soils—(*i*) calcareous clayey soil (*ii*) sandstone soil (*iii*) basalt black cotton soil (*iv*) granite soil (*v*) laterite soil.

II—Transported soil—(*vi*) alluvial soil of Narmada ravines.

Methods of Study

A. Root Systems :

The root systems were studied in the soils situated on the different geological formations already described.

Competition effects development of the roots hence only plants growing with less competition were selected. First a circular trench was dug round the plant with sufficient radius to avoid breaking of roots. Next the soil from the side of the trench towards the plant was very carefully removed. Extreme care was taken so that the falling soil may not damage the delicate rootlets. The diameter of the roots usually helped in guessing the root length but sometimes it utterly failed. Still the main root and its branches were followed as far as possible.

The roots together with the adhering soil were brought to the laboratory with every possible precaution. The roots were then loosened in a bucket of water and finally washed with a jet of water. Lastly, the complete root system was spread on a graph paper, arranged as nearly as possible in the natural position in a vertical plane and traced with care to exact measurement. The drawing carefully made represents the root system even more fully and accurately than a photograph (cf. Weaver, 1925).

B. Soil Physical Characters :

All the 6 types of soils, as described earlier, were examined by trench profiles. Samples were collected from the top 5 cm., 30 cm., 60 cm., and 100 cm. depth. They were analysed for the following characters :

(*i*) moisture content (*ii*) water holding capacity (*iii*) texture and (*iv*) pore space.

Usual methods as outlined by Piper (1947) were followed for these determinations.

PRESENTATION OF DATA

A. Soil Physical Characters of the Trench Profile :

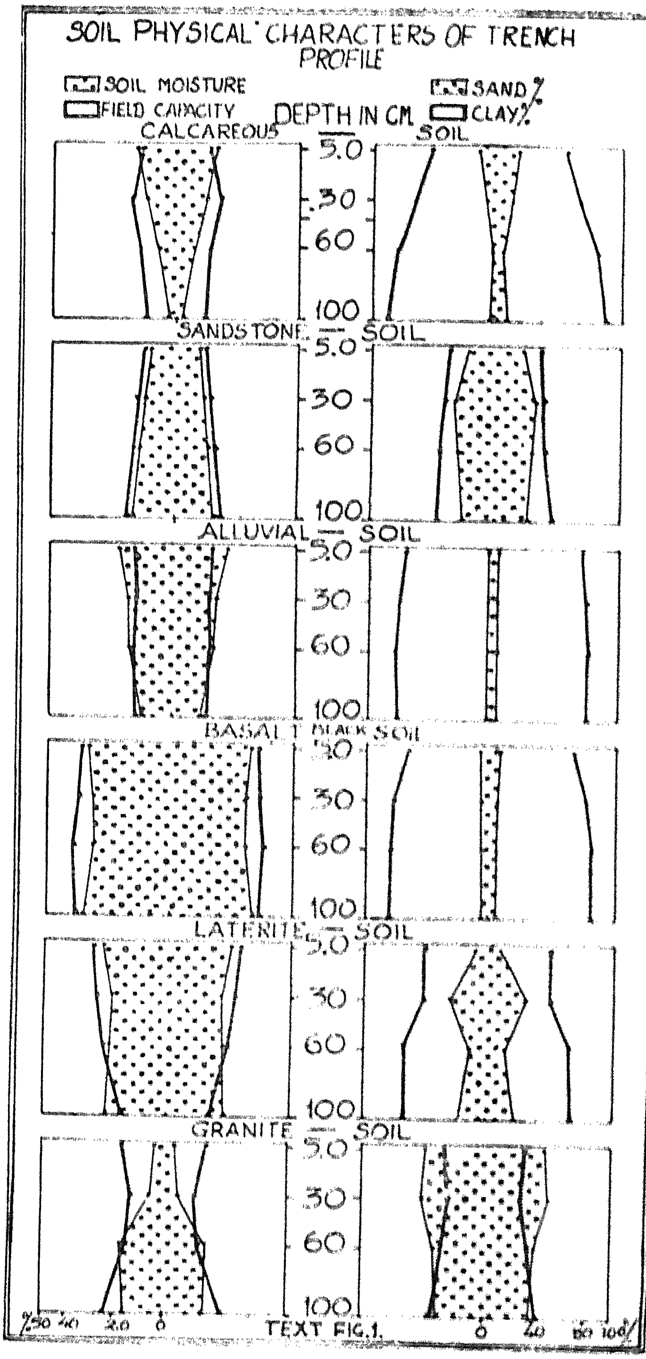
The soil physical characters of the respective profiles are presented in table 1 and text figure 1.

TABLE 1

Soil Physical Characters of Different Trench Profiles at Jabalpur

DATE : August/September, 1957.

Soil type & locality	Depth of soil sample in cm.	In gm. percentage of dry wt.						Sand/Clay
		Soil water	Field capacity	Porosity	Sand & gravel	Silt	Clay	
Calcareous Clayey Soil (Foot of Bada Simla)	5	15·14	13·51	—	15·49	30·11	54·40	0·285
	30	11·14	17·37	39·80	9·90	24·10	66·00	0·150
	60	7·41	13·93	—	4·10	17·90	79·00	0·052
	100	3·31	12·04	—	4·90	11·00	88·10	0·022
Sandstone Soil (Behind M.M.V. Science block)	5	9·53	10·75	—	22·03	42·00	35·96	0·613
	30	10·62	14·85	44·03	31·90	27·10	41·00	0·778
	60	13·32	14·42	—	28·90	28·10	43·00	0·672
	100	14·46	14·95	—	26·50	26·90	46·60	0·569
Alluvial Soil (River Narmada ravines)	5	20·99	16·75	—	4·52	26·05	69·45	0·065
	30	18·55	15·27	36·81	4·40	22·50	73·10	0 060
	60	17·77	16·28	—	4·10	18·80	77·10	0·053
	100	11·05	14·88	—	2·90	22·50	76·60	0·038
Basalt Black Soil (Near local C.O.D.)	5	533·33	35·92	—	8·21	25·73	66·06	0·124
	30	31·73	36·61	39·02	5·40	16·10	78·50	0·069
	60	31·67	38 55	—	5·00	15·30	79·70	0·063
	100	34·05	34·95	—	6·20	13·70	80·10	0·077
Laterite Soil (Top of basalt hillocks on way to aerodrome)	5	26·26	30·04	—	9·73	39·42	50·85	0·191
	30	21·95	27·32	43·08	26·50	22·50	51·00	0·519
	60	22·10	22·55	—	12·30	21·50	66·20	0·186
	100	23·61	19·47	—	21·00	18·00	66·10	0·318
Granite Soil (Foot of Madan Mahal Hills)	5	3·74	16·96	—	47·00	19·50	33·50	1·403
	30	5·21	12·74	43·58	50·20	18·30	31·50	1·594
	60	16·82	16·62	—	40·80	21·00	38·20	1·069
	100	16·55	23·73	—	39·10	18·80	42·10	0·930



TEXT FIG. 1.

The following points are noteworthy :—

(*a*) The highest moisture content and water holding capacity were observed in basalt black cotton soil, being 31·67 to 34·05% and 54·95 to 38·55%, respectively.

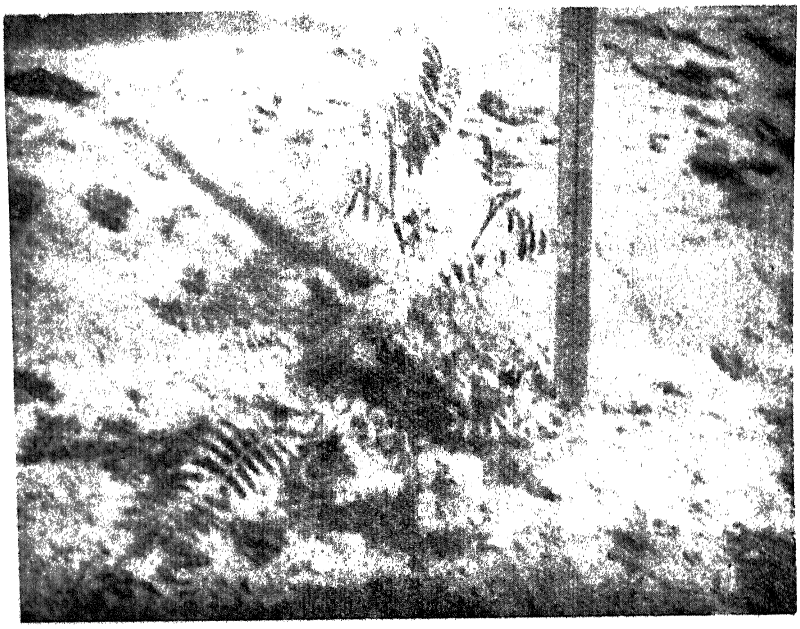
(b) The maximum of sand percentage was recorded in granite soils lying in between 39·1 to 50·2.

(c) The percentage of clay was observed highest in calcareous clays, being 54·4 to 88·1. The second higher was in basalt black soil and alluvial soil, being 66·06 to 80·1 and 69·45 to 76·6, respectively.

(d) The maximum pore space was found in sandstone soils, being 54·03%. The next near figures were in granite (43·58%) and laterite (43·08%) soils.

B. Root Systems of *Tephrosia purpurea* :

The plant belonging to the family Leguminosae, sub-family Papilinaceae is a copiously branched, sub-erect, herbaceous wild annual to perennial; 30 to 60 cm. high bearing 5 or more tender branches (text fig. 2). It possesses a prominent tap



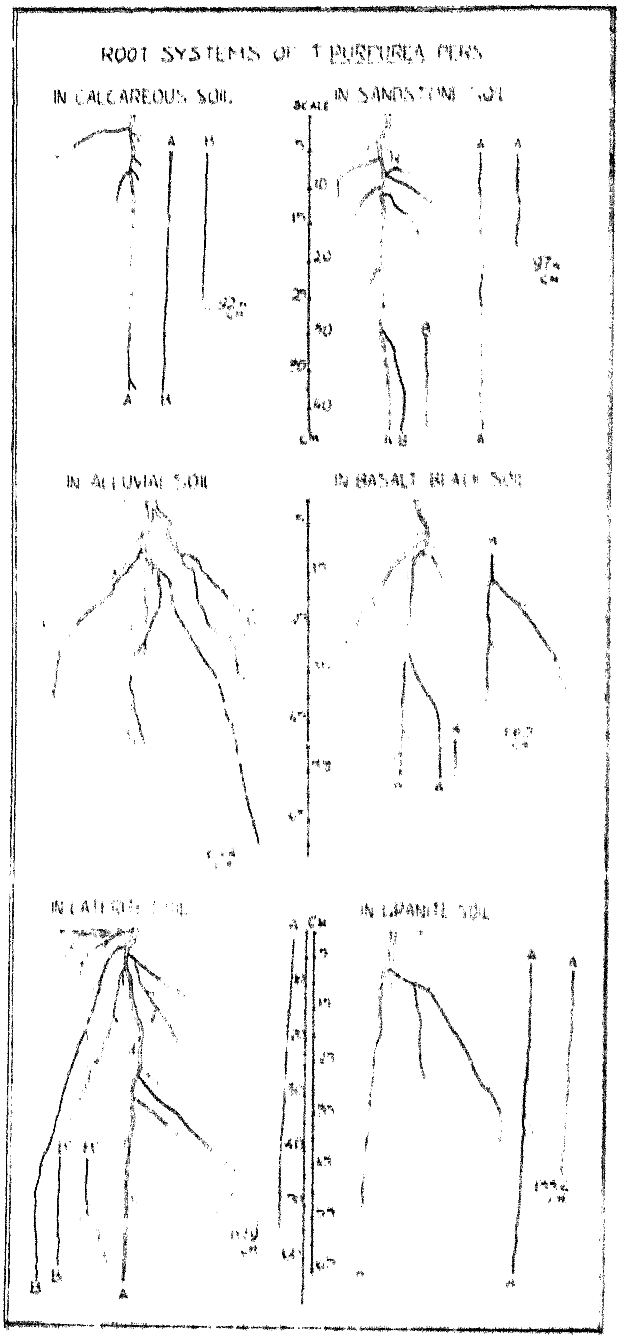
Text Fig. 2. *Tephrosia purpurea* Pers., showing a bushy habit.

root, 2 or 3 times the length of stem, extensively branched; laterals long, stout and branched. The following is the description of the root system as found in different soil types. The same is given in table 2 and text fig. 3.

1. In Calcareous Soil (Clayey) :

Here the plant possesses a small vertically penetrating downwards narrowly spreading and scarcely branching slender tap root system. The maximum depth of root penetration here was recorded to be 92·4 cm. on 31st July, 1957. The root length here is 3 to 4 times the stem height. The branching is less here, the number of laterals being 8 to 10. Laterals are slender and less branched. The branching

starts just below the soil surface and the first few laterals run horizontally to the extent of 10 to 12·5 cm. Next the laterals turn downwards after running a little distance obliquely. Lower down the laterals are scarce.



Text Fig. 3

2. Alluvial Soil :

In this soil the plant showed a less penetrating, widely spreading and profusely branching stout tap root. The maximum depth of root penetration was found to be 69·4 cm. here. Branching starts even at the soil surface. The branching is so vigorous here that the primary tap root is difficult to be identified among the secondary roots. After about 15 cm. the tap root gets divided into two stout bran. ches. Laterals are abundantly branched and moderately long; longest measuring 20·5 cm. Thus the root system in this type of soil is small with considerable lateral spread.

Table 2

Root Habits of *Tephrosia purpurea* in Different Soil Types

Date : August September, 1957.

No.	Soil type	Max. root length	Lateral spread	Root condition	Root branching
1.	Calcareous soil	92·4 cm.	10—13 cm.	Slender & small	Least
2.	Sandstone soil	97·4 ,,	10—13 ,,	Stout & long	Less
3.	Alluvial soil	69·4 ,,	12—21 ,,	Stout & small	Copious
4.	Basalt black soil	88·5 ,,	15—18 ,,	Stout & small	Less
5.	Laterite soil	117·9 ,,	25—28 ,,	Stout & long	Copious
6.	Granite soil	135·6 ,,	17—21 ,,	Stout, woody & long.	Less

3. Sandstone Soil :

The plant, here, possessed a stout tap root, growing vertically downwards with very little lateral spread. The maximum length of the main root was 97·4 cm. Branching was less. Branching starts 2 to 5 cm. from the junction of stem and the root.

4. Basalt Black Soil :

In this soil type the tap root was observed to be only moderately long, widely spreading and less branched. It was stout and growing vertically downwards. The maximum length of the main root being 88·5 cm. Branching starts 5 to 8 cm. below the soil surface. Laterals are stout, 25 to 30 cm. and less branched. Upper lateral branches ran somewhat horizontally to a little extent before becoming oblique. Below 10 cm. from the soil surface the laterals are less. Lateral spread was 15 to 18 cm. sideways. Thus here the root system is small and with marked lateral spread.

5. In Laterite Soil :

The stout and woody tap root, here, grows considerably deep going almost vertically downwards to 117·9 cm. It is widely spreading and moderately branched. The tap root bifurcates at a distance of 5 to 8 cm. Branching starts even from the

soil surface. The lateral branches are slender and much branched themselves. They spread almost horizontally extending sideways upto 15 cm. Thus the root system here is deep one with considerable lateral spread.

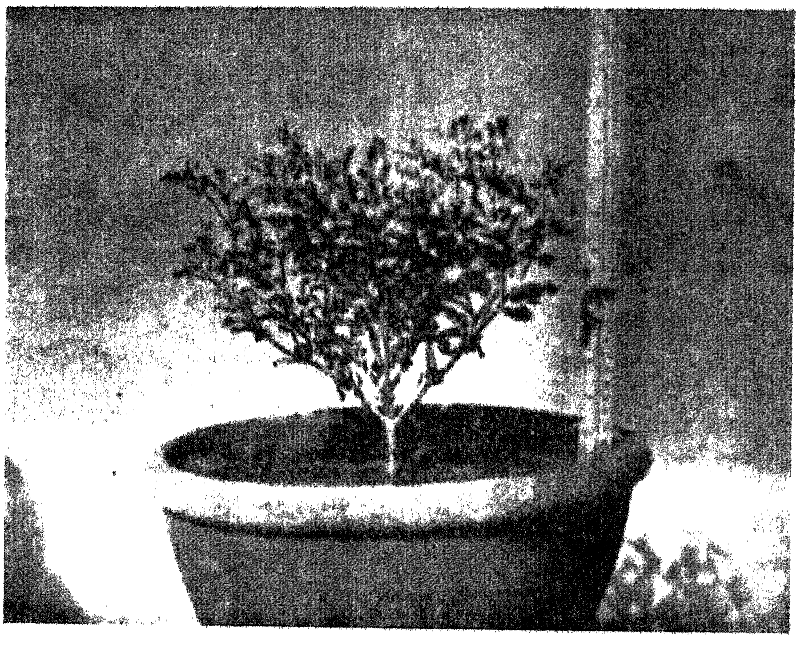
6. In Granite Soil :

The stout tap root in this soil was observed to be exceptionally long, penetrating almost vertically downwards and measuring 135·6 cm. The system is less branched here. The laterals when present are considerably stout extending to a maximum of 17 to 20 cm. and in turn are less branched. Branching starts from about 6 cm. from the soil surface. After running a little distance the tap root divides into two, one growing vertically downwards and the other running obliquely and extending upto about 20 cm. It branches in the way and then runs downwards parallel to the tap root. However, unfortunately it could not be traced beyond 42·5 cm. Thus it examplifies a deep root system with little lateral spread.

Thus *Tephrosia purpurea* shows a small but copious branched root system in alluvium, considerably long and branched in laterite and basalt and a long but less branched root system in granite, sandstone and calcareous soils.

C. Root System of *Acanthospermum hispidum* DC.

The plant belonging to the family Compositae is a new species to India and has become widespread in a very short period of time. It is a slender, branched, sub-erect. herbaceous wild annual going upto about 1 meter (text fig. 4). It has a small branched tap root system. It shows the following variations in the root systems in the different soils : (cf. table 3)

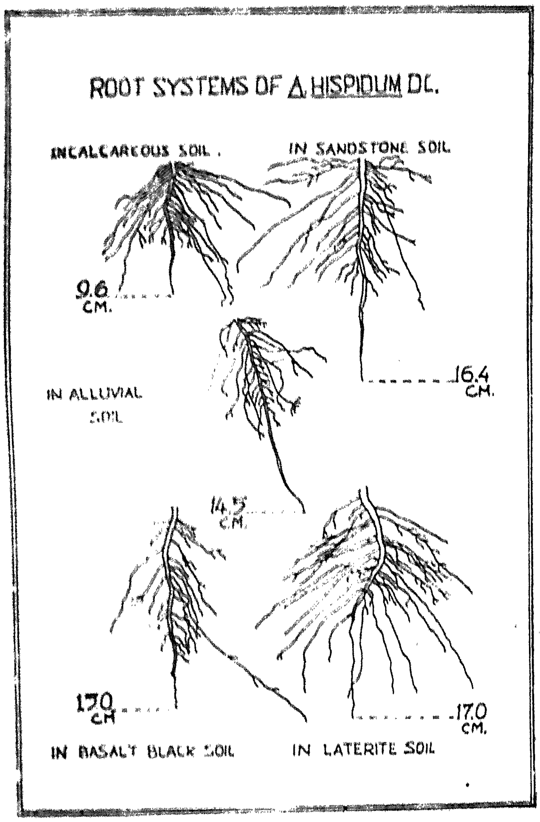


Text Fig. 4. *Acanthospermum Hispidum* DC., Note the Dichotomous type of Branching.

1. Incalcareous Soil :

Here the plant has a shallow root system with considerable lateral spread. The tap root measures only 9·6 cm. here. Total number of laterals is only 2 dozens

in this habitat. Laterals are slender and less branched. Maximum number of laterals occur near the surface of the soil.



Text Fig. 5.

2. In Sandstone Soil :

The plant possesses a long and considerably branched root system here. The maximum length of the tap root was 16·4 cm. and going vertically downwards. Laterals are slender, long and less branched. Branching of the tap root starts just near the soil surface. Laterals which are 6 to 7 in number run almost horizontally and spreading to a maximum of 7·6 cm.

3. In Alluvial Soil :

The slender tap root grows almost vertically downwards in this soil type. The main root measures 14·5 cm. Branching was less. Lateral branches are very slender, rarely branched and only moderately long; the longest being 6·5 cm. Branching is just near the soil surface. Thus the root system here is small with less of branching.

4. In Basalt Black Soil :

Here the plant has a moderately long, slender and prominent tap root. Branching is less here. Length of the main root was 15 cm. Branching started within 2·5 cm. of the tap root spreading upto 5 cm. Laterals occur in more abundance in the 5, 7·5 and 10 cm. of the tap root. The maximum lateral spread was found to be 9 cm.

5. In Laterite Soil :

Here the tap root was found to be spreading and profusely branching. The main root measured 17 cm. It bifurcates at a distance of 9 cm. Number of lateral branches exceeds 3 dozen. They are stouter, slightly branched and longer; maximum length being 9·5 cm. Branching starts just below the soil surface. The first 2·5 cm. of the tap root bears 7 to 8 slightly branched laterals. Laterals increase in the 5 and 7·5 cm. of the main root. Thus the root here is longest and branched with good spread.

The root system could not be studied in granite soil.

It is concluded that *A. hispidum* shows some differences in it's root system in the different soil types. In calcareous soil, sandstone and laterite soils the root systems are more branched and small and in basalt and alluvial soils they are longer and less branched.

TABLE 3

Root System of *Acanthospermum hispidum* in Different Soil Types

Date : August/September, 1957

No.	Soil type	Maximum root length	Lateral root spread	Root condition	Root branching
1.	Calcareous soil	9·6 cm.	7·5—10·0 cm.	Slender & small	Moderate
2.	Sandstone soil	16 4 ,,	10·0 - 11·3 ,,	Slender & long	Moderate
3.	Alluvial soil	14·5 ,,	5·0 - 7·6 ,,	Slender & small	Less
4.	Basalt black soil	15·0 ,,	7·5 - 9·0 ,,	Slender & small	Less
5.	Laterite soil	17·0 ,,	10·0 - 11·5 ,,	Stout & long	Profuse

DISCUSSION

While dealing with water in relation to structure and growth of plants Misra and Puri (1954) have observed that the development of root system depends upon the amount of moisture present in the soil although in most cases it is governed by the heriditary character. Muller (1946) has concluded that the facility with which roots may penetrate the soil may largely be effected by the extent of useable soil moisture, and at the same time root distribution may get modified in light of this availability. Literature bearing on such conclusion has already been described in the text. The various soil physical characters which appear to be responsible or

which effect the growth and distribution of roots of the two plants under study shall be discussed here.

Tephrosia purpurea : As per table 2 the maximum length of the main root recorded is in the granite soil, being 135·6 cm. The minimum length was observed in alluvial soil at Narmada Ravines. In granite soil the moisture is kept low and increases with increasing depth. Sand/Clay fraction of the soil is highest, being from 0·9 to 1·59. It appears that due to the easy facilities offered to the roots here they tend to go down in search of water. On the other hand Sand/Clay fraction in alluvium is low, being 0 03 to 0·06 : water content is moderately high in these soils. Roots are not long here but branching is copious even just below the soil surface. Further, porosity of soil also appears to have a direct bearing on root length. In general roots are longer with higher porosity.

It appears from the above study that *Tephrosia purpur ea* has long root system in sandy soils with less moisture and high porosity. In high moisture level it tends to branch copiously near the surface of soil. Thus low moisture, high porosity and high Sand/Clay fraction appear to favour root length. The reverse appears to facilitate copious branching and shallow roots.

Acanthospermum hispidum : The length of main root of this plant has been recorded to be longest in laterite and sandstone soils (tables 1 and 2). Sand/ Clay fraction in these soils is not much but porosity works out to 43·08 and 44·03%, respectively. It is less developed in calyey soils. In higher soil moisture (in basalt black soil) the root system is only medium.

It appears from the foregoing study that Sand/Clay fraction, porosity and soil moisture are the most important factors in determining the root development.

SUMMARY

The present investigation was undertaken to study the root development of two abundantly growing plants, *Tephrosia purpurea* Pers. and *Acanthospermum hispidum* DC., as effected by different soil physical conditions, viz., soil moisture, field capacity, texture and porosity. Root systems were studied in the soils derived from the 6 geological formations of Jabalpur. Soil physical characters have been correlated with the root structure. It has been observed that :—

Tephrosia purpurea has a long root system in sandy soils with less moisture and high porosity. In high moisture level it tends to branch copiously near the soil surface.

Acanthospermum hispidum has long roots where the porosity of the soil is high. It is less developed in clayey soils, and is copiously branched in moist soils.

The study further shows that Sand/clay fraction, porosity and soil moisture are the most important factors in determining the root development.

ACKNOWLEDGEMENTS

The authors desire to express their gratitude to Professor R. Misra for approving the work and to Dr. R. L. Nirula, the then Principal, Mahakoshal Mahavidyalaya, Jabalpur for facilities.

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OSSIFICATION OF THE SKULL AND JAW ARTICULATION IN *OPHICEPHALUS PUNCTATUS* (BLOCH)

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[Received on 10th March 1959.]

INTRODUCTION

Ophicephalus punctatus belongs to the family Ophicephalidae and Order Ophicephaliformes (Berg). It is a fresh water fish abundant in stagnant shallow waters throughout India. The fish is predatory and possesses an accessory respiratory organ. The development and morphology of the chondrocranium (Swarup 1954, 1955) and the morphology of the skull (Swarup 1956, 1957) of this fish have already been described. The present paper deals with the ossification of the bones of the skull and gives an account of the articulation of the jaws.

MATERIAL AND TECHNIQUE

For the purpose of present study, the eggs of *O. punctatus* were collected from Sagar Lake and the young ones reared in the laboratory. Embryos in various stages of development were also obtained from the Sagar Lake. Some of the stages were serially cut and stained with Mallory's Triple Stain while others were stained with Alizarine Red as recommended by Gray (1929) and whole mounts of these were made. Some stages were studied by the wax plate reconstruction method according to the method described by the author (1953).

OBSERVATIONS

Two kinds of bones are distinguished, the cartilage bones as ossifications developed solely beneath the perichondrium and the dermal bones as ossifications developed solely outside the perichondrium. As a general rule the two kinds of bones remain separate in the adults but in some cases the two elements may fuse to form single bones.

Cartilage bones :

The cartilage bones, since they are preformed in already existing cartilage, present no problem as regards their development. A summary of the cartilage bones formed is given below (Figs. 1, 2, 6 and 7).

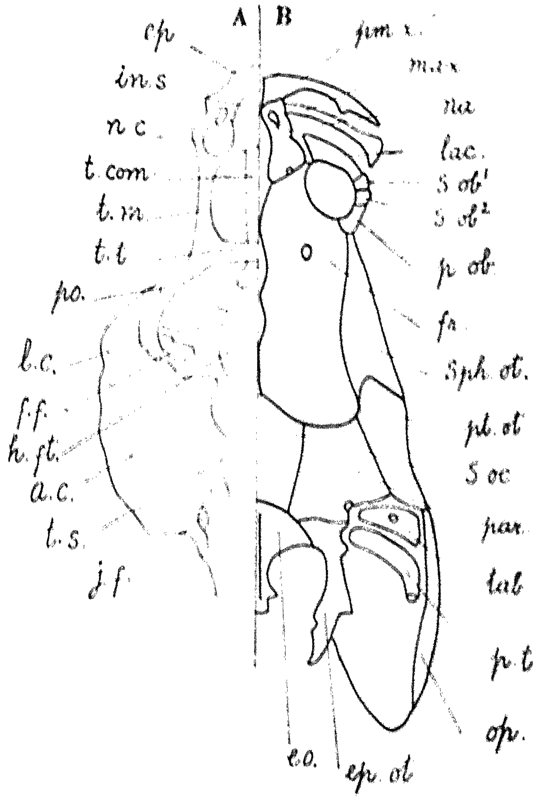


Fig. 1A and 1B : *Ophicephalus punctatus.*

1A. Left side of the wax model reconstruction of 7·5 mm stage chondrocranium in dorsal view : a.c.=auditory capsule ; ep.=ethmoid plate ; f.f.=facial foramen ; h. ft.=hypophy ial fenestra ; in. s.=internasal septum ; j. f. =jugular foramen ; l. c.=lateral commissure ; n c.=nasal capsule ; po. =post orbital process of au litory capsule ; t. com. = trabecula communis ; t. m.=orbital cartilage ; t. s.=tectum synoticum ; t. t.=tectum transeversum.

1B. Right side of the skull of an adult fish : ep. ot.=epiotic ; eo.=exoccipital ; fr.=frontal ; lac.=lacrymal ; max.=maxilla ; na.=nasal ; op =opercle ; par. =parietal; pm. x.= premaxilla ; p. ob.=post-orbital ; p. t.=posttemporal ; pt. ot. =pterotic ; s. ob =suborbital; s. oc.=supraoccipital ; sph. ot.=sphenotic ; tab.=tabular.

A. Neurocranium :

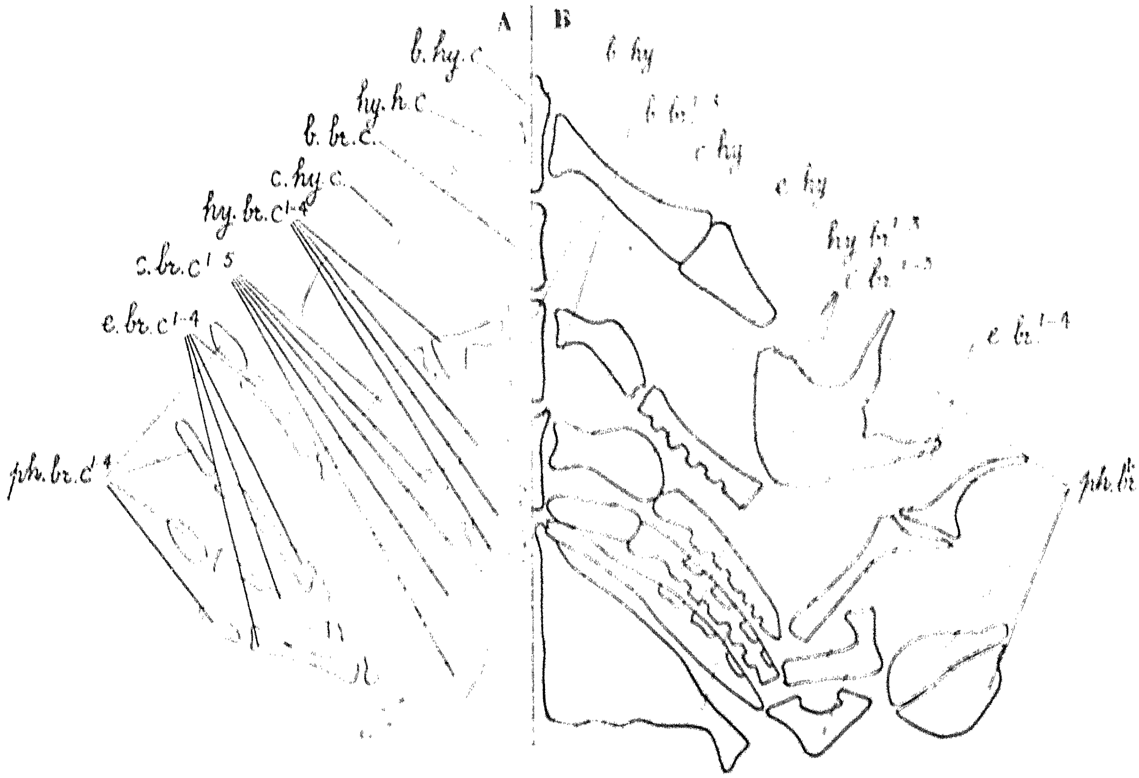
Chondrocranium	*Cartilage bones*
1. Ethmoid Region	Mesethmoid (single) Ectethmoid (paired)
2. Auditory Region	Sphenotic (paired) Pterotic (paired) Epiotic (paired) Prootic (paired)
3. Occipital Region	Supraoccipital (single) Exoccipital (paired) Basioccipital (single)

B. Splanchnocranium :

Chondrocranium	*Cartilage bones*
4. Mandibular Arch	
(*i*) Pterygoquadrate cartilage	Metapterygoid (paired) Quadrate (paired)
(*ii*) Meckel's cartilage	Articular (paired) Angular (paired)
5. Hyoid Arch	
(*i*) Hyosymplectic	Hyomandibular (paired) Symplectic (paired)
(*ii*) Hypohyal and Ceratohyal	Ceratohyal and Epihyal (paired)
(*iii*) Interhyal	Interhyal (paired)
6. Branchial Arches	
Each of the first, second, third and fourth arch consists of paired hypo—, cerato—, epi—, and pharyngobranchials. The fifth arch consists only of the paired ceratobranchials.	Each of the first, second and third arch consists of paired hypo—, cerato—, epi—, and pharyngobranchials while the fourth arch consists of paired cerato—, epi—, and pharyngobranchials. The fifth arch consists only of the paired ceratobranchials.
7. Copula	
Consist of a basihyal and a basibranchial.	Consists of a basihyal and three basibranchials.

In the formation of the cartilage bones the following points are interesting :

1. The sphenotic, pterotic, supra-occipital, metapterygoid, articular and angular bones have double origin. They are formed in the cartilage and then dermal bones overlap them and finally the two bones become fused (Figs. 1, 5, 6, and 7).



Figs. 2A and 2B : *Ophicephalus punctatus*.

2A. Left side of the hyoid and branchial cartilages of a 7·5 mm stage chondrocranium : b. br. c. = basibranchial ; b. hy. c. = basihyal ; c. br. c. = ceratobranchial ; c. hy. c. = ceratohyal ; e. br. c. = epibranchial ; hy. br. c. = hypobranchial ; hy. h. c. = hypohyal ; ph. br. c. = pharyngobranchial ;

2B. Right side of the hyoid and branchial bones of the adult.

2. The epibranchial bone of the first arch on each side is in the form of a large, thin flattened bone whose dorsal surface is hollowed out to form a large shallow concavity which forms the base of the suprabranchial cavity (Fig. 2)

3. The pharyngobranchials of the third and fourth arches on each side are closely attached to one another to form a thick oval bone known as the superior pharyngeals whose ventral surface show a rounded area covered with numerous small conical teeth (Fig. 2)

4. The ceratobranchials of the fifth arch are in the form of a pair of large thick triangular bones known as the inferior pharyngeals whose dorsal surface is covered with numerous sharp conical teeth (Fig. 2)

Dermal bones :

The dermal bones which appear round the neuromasts of the lateral lines may develop independently or may join with the neighbouring rudiments to form adult bones. Inspite of the modifications of the dermal bones in the adult, the process of ossification has been employed as a very reliable source for the identification and comparision of individual bones and the successful tracing out of homologies.

The nomenclature employed by various authors to certain dermal bones is very variable and sometimes confusion arises if their proper homologies are not understood. In the present account the author has followed the terminology used by Goodrich (1930) and Gregory (1951).

1. Ethmoid Region

The maxillae and premaxillae appear as paired bones in the upper jaw of a 3 mm stage of the fish (Fig. 3). They are simple rods lying parallel to each other transversely one behind the other. There are no teeth visible on the premaxillae at this stage and both premaxillae and maxillae appear very similar to each other. However, at 5 mm stage (Fig. 4) teeth appear in the anterior pair of rods on their outer margins. These are the premaxillae which gradually assume their characteristic curved sabre shape. Proximally each premaxilla articulates with the mesethmoid while distally it is free. The posterior pair of rods, the maxillae, remain without teeth throughout and develop in the form of slender elongated bony rods which articulate proximally with the premaxillae and distally with the lower jaw.

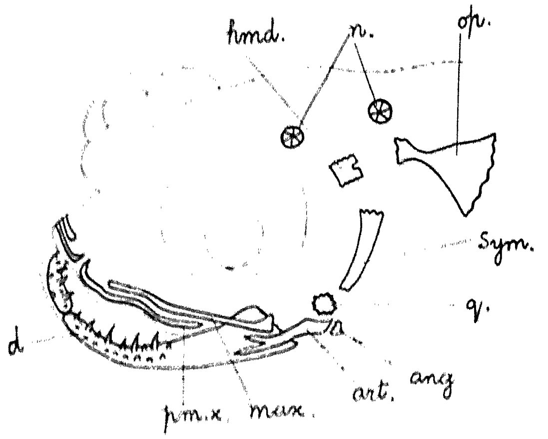


Fig. 3. Diagram showing the bones of the head in 3 mm stage *Ophiocephalus punctatus* after alizarine preparation: ang. = angular; art. = articular; d. = dentary; hmd = hyomandibular; n. = neuromast; q. = quadrate; sym. = symplectic; rest as in fig. IB.

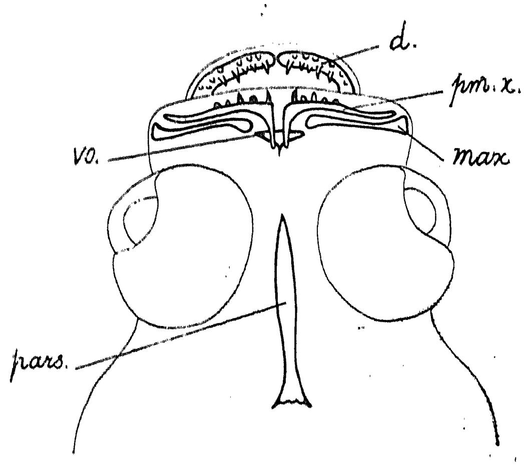


Fig. 4. Diagram showing the bones of the head in 5 mm stage *Ophiocephalus punctatus* after alizarine preparation: pars. = parasphenoid; vo. = vomer; rest as in fig. 3.

The paired nasals and lacrymals are seen at 15 mm stage (Fig. 6 a). Each nasal arises from a single centre of ossification and at an early stage shows its two limbs curved in opposite directions. One limb of the bone lies over the olfactory organ while the other beneath the lateral line canal. When fully formed each nasal

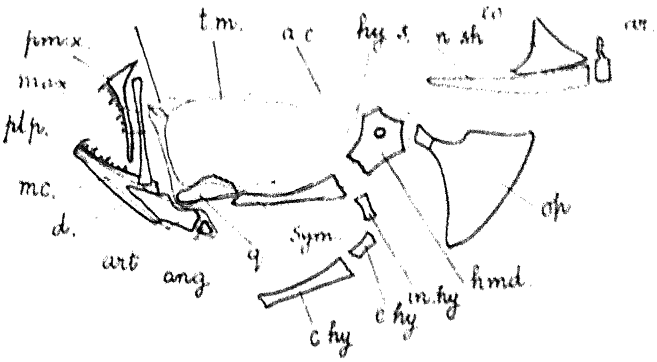


Fig. 5. Diagram of the skull bones of 8 mm stage *Ophicephalus punctatus* after alizarine preparation: ar. = arcualia ; hy. s. = hyosymplectic ; in. hy. = interhyal ; m. c. = Meckel's cartilage; n. sh. = notochordal sheath ; ptp. = pterygoqudrate ; rest as in figs 1 and 3.

is in the form of a triangular bone and shows a small opening in its anterior part through which the lateral line canal opens to the outside. Lacrymals are simple elongated bones and form the anterior-most piece of the orbital series of bones (Figs. 1B and 7).

2. Orbital Region

At 30 mm stage five orbital bones including the lacrymal are seen round each eye (Fig. 7). These are, one lacrymal, one antorbital, two suborbitals, and one postorbital. Since in the adult the antorbitals are absent (Fig. 1B), it is assumed that they fuse with the lacrymals of their sides. The orbital bones which form the lower margin of the orbit extend from the nasal to the frontal and are traversed by the lateral line canal.

3. Temporal Region

There are four bones on each side of the adult skull in the temporal region. The relation of these four bones to the lateral line (Fig. 7) indicates their homologies. The posterior-most arises in relation with the pectoral girdle and hence can be easily termed as post-temporal. If this bone is post-temporal then it would formulate the others as tabular, pterotic and sphenotic from behind anteriorwards. The pterotic and the sphenotic bones are of double origin and at 15 mm stage (Fig. 6 c,d) they are seen to arise in cartilage as cartilage bones as well as round the lateral line as dermal bones. The two elements, the cartilage bone and the dermal bone later fuse to form mixed bones. The sphenotics and pterotics are elongated flat bones and possess longitudinal articulating grooves on their ventral side for hyomandibular bone. The tabular and post-temporal are entirely dermal in origin. Both these bones are pierced by foramena, the former in the middle while the latter at the posterior end through which the lateral line opens to the outside.

4. Dorsal Region

At 3 mm stage one pair of neuromasts are seen on either side, one behind the other (Fig. 3). These neuromasts become the centre of activity and from them radiating growth lines of bone are seen to emerge out. The anterior pair of neuromasts forms the frontals while the posterior pair forms the parietals. At 15 mm stage the frontals and parietals are seen as rudiments of bone (Fig. 6 b,c,d). At 30 mm stage each frontal is seen to arise by two ossifications (Fig. 7). That part of the frontal which is anterior and lies dorsally to the orbit is the first to be formed and may represent supraorbital. The posterior part of the frontal appears

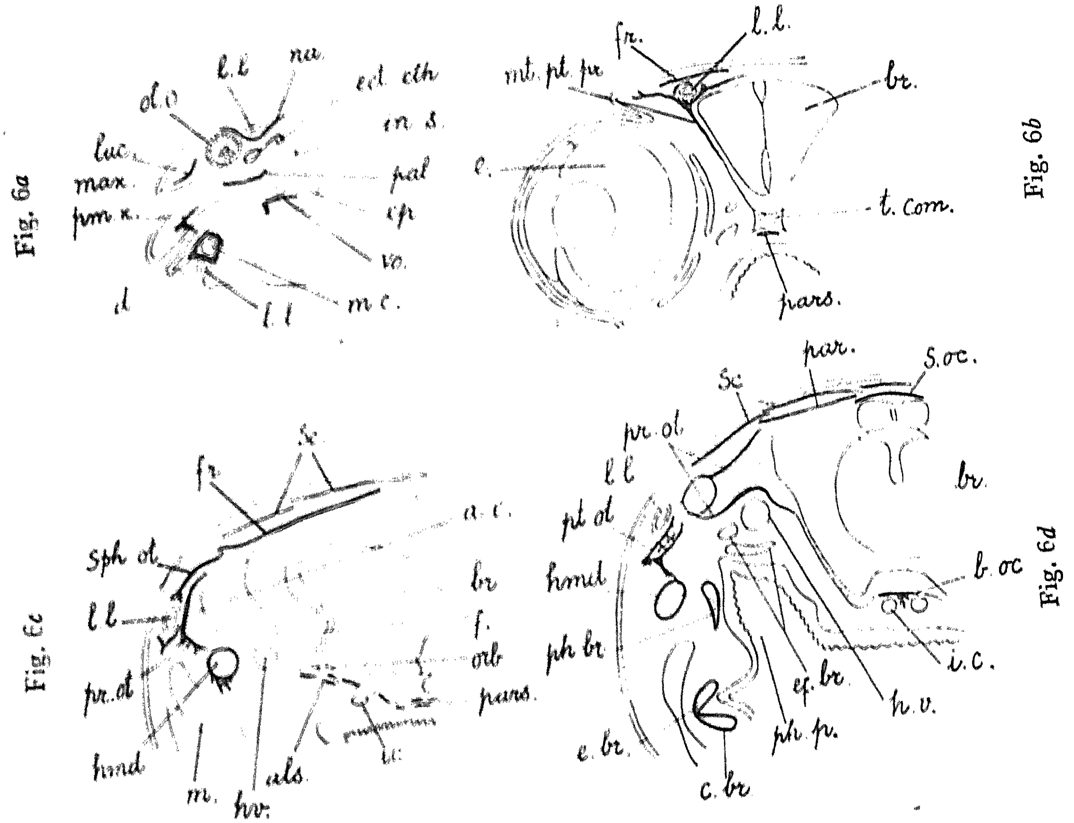


Fig. 6. Transverse sections of a 15 mm stage *Ophicephalus punctatus* :

a. through the olfactory region : ect. eth.=ectethmoid ; l. l.=lateral line canal ; pal.= palatine ; rest as in figs. 1, 4 and 5.

b. through the eye region : br.=brain ; e.=eye ; mt. pt. pr.=metapterygoid procees ; rest as in figs. 1 and 4.

c. through the auditory region : al. sp.=alisphenoid · f=facial nerve ; hv.=head vein ; m.= muscle ; pr. ot.=prootic ; sc.=scale ; rest as in figs. 1, 4 and 5.

d. through the post-auditory region: b. oc=basioccipital; ef br. =efferent branchial artery ; i. c=internal carotid artery ; ph. p.=suprabranchial organ; rest as in figs. 1, 2 and 5.

very late and fuses with the anterior part. Each frontal is in the form of large, elongated and rectangular bone which forms more than half the entire dorsal surface of the skull. Through the anterior part of the frontal a lateral line passes to the nasal. The parietals which also appear very late, are formed behind the

frontals and are comparatively small, quadrangular bones covering the posterior part of the orbitotemporal region. The two parietals are widely separated because of the development of a cartilage bone in between the two parietals (Figs. 1 and 6 d). This is the supraoccipital bone. At 30 mm stage a dermal bone is laid in between the two parietals and in front of the supraoccipital with which it fuses. Thus supraoccipital is formed as a mixed bone. The dermal part of the supraoccipital is quite smooth but its part of the cartilage bone which lies posteroventrally shows three cup-like areas articulating posteriorly with the exoccipitals. All these bones, the paired frontals, parietals and the median supraoccipital, sink down below the level of the surface and become intimately connected with the chondrocranium.

5. Palate

Vomer arises as a median bone at 5 mm stage and lies just behind the maxillae (Fig. 4). It arises from a single centre of ossification and is devoid of teeth when first appears. Teeth appear later on its ventral side (Fig. 6 a). The vomer consists of a thick and broad anterior end and a thin posterior elongated process. Parasphenoid also arises as a median bone behind the vomer at 5 mm stage (Fig. 4). In the beginning it is just like a thin rod-like structure far removed from the vomer but later it develops wings and extends far forwards and comes to lie dorsal to the vomer. Posteriorly the parasphenoid lies closely attached to the basioccipital. Palatines are visible at 15 mm stage (Fig. 6 a) as small flat triangular bones lying on either side of the vomer. Ectopterygoids, endopterygoids and metapterygoids which were not visible at 8 mm stage are seen fully formed at 30 mm stage. That part of the metapterygoid which is in contact with the quadrate, symplectic, and hyomandibular originates as a cartilage bone and this later fuses with a dermal piece developing dorsal to it.

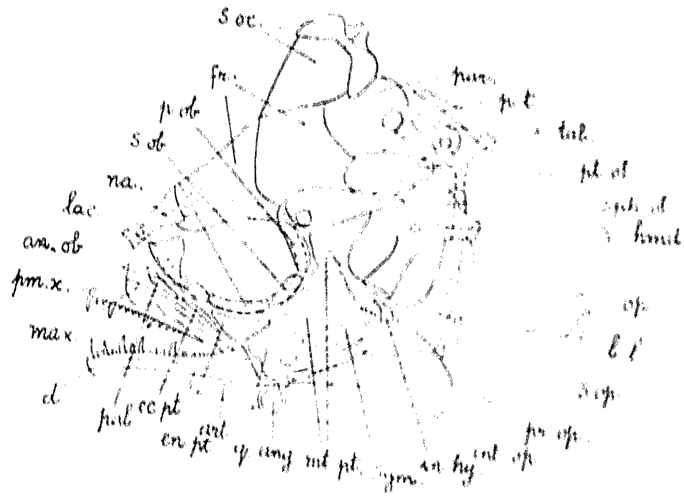


Fig. 7. Diagram of the skull bones of 30 mm stage *Ophiocephalus punctatus* after alizarine preparation: an. ob. = antorbital; ec. pt. = ectopterygoid; en. pt. = endopterygoid; int. op. = interopercle; pr. op. = preopercle; s. op. = subopercle; rest as in figs. 1, 5 and 6.

6. Lower Jaw

Each dentary begins as an ossification in the region of the extreme anterior end of the Meckel's cartilage and is the first bone to appear (Fig. 3). It spreads along the whole of the lower jaw and takes the shape of a strong curved bone with

numerous teeth on its upper surface. Each dentary is traversed by a lateral line canal. The articular and angular which originate as cartilage bones become covered over later by dermal bones of the same name (Fig. 3). Each articular is in the form of a triangular bone, the anterior apex of which is forked in which the posterior end of the dentary fits in. Angular is a small bone posterior to the articular with which it fuses later on.

7. Other Dermal Bones

Other dermal bones which develop in the skull are the bones of the paired opercular series and the median urohyal. Opercular is the largest and most prominent bone of the series and is seen to appear at 3 mm stage (Fig. 3). It is a thin flattened bone and along its antero-dorsal corner shows a facet for articulation with the hyomandibular. The other bones of the series, the preopercular, subopercular, and the interopercular arise much later (Fig. 7). The preopercular is a crescentic bone lying in association with the hyomandibular, symplectic and the quadrate. It is traversed by a lateral line canal which is continued infront in the lower jaw. The subopercular and interopercular are broad flattened bones lying ventral to the opercular and preopercular.

The urohyal appears at 30 mm stage and is in the form of a small membranous and laterally compressed bone situated in the mid-ventral line below the basihyal and in between the two ceratohyals.

Jaw articulation :

At 5·2 mm stage the jaws are formed by the pterygoquadrate and the Meckel's cartilages. The articulation of the jaws with the chondrocranium is provided at two places, in the region of the auditory capsules by hyosymplectic and in the region of the ethmoid plate by pterygoquadrate. This type of jaw suspension has been called the methyostylic type. At about 8 mm stage ossification sets in the hyosymplectic cartilage at two centres giving rise to the hyomandibular bone and the symplectic bone (Fig. 5) . At the same stage ossification is seen to set in the pterygoquadrate at one centre forming the quadrate bone. Since the dermal jaws make their appearance by this time, the quadrate bone now articulates the dermal lower jaw *i. e.* articular and dentary, with the hyomandibular bone through the symplectic. The hyomandibular bone in its turn is suspended with the auditory capsule which is still unossified at this stage. When the metapterygoid bone has made its appearaace, it establishes its connection with the skull infront of the palatine nerve. Thus the skull comes to possess two jaw articulations, one through the hyomandibular and the other through the metapterygoid. This is the amphistylic type of jaw articulation.

DISCUSSION

The contension of Moy-Thomas (1934) that in teeth bearing bones, the teeth appear first and that the bone is formed by fusion of the individual teeth is not confirmed. The premaxillae, vomer and the palatines when they first appear in *O. punctatus* are without teeth.

The nasals in *O. punctatus* arise from a single centre of ossification. In *Polypterus* there are three centres of ossification which remain separate and form three bones, nasal, adnasal and terminale (Goodrich 1909). In *Amia* also there are three centres of ossification but later they fuse to form a single unit called nasal (Goodrich 1909) . Since the nasal of *Amia* and *O. punctatus* occupy similar positions they may be considered homologous structures.

There is some dispute as regards the nomenclature of the bones of the temporal region in different fishes. Following Gregory (1951) in the Palaeoniscoids there are a pair of bones called extra scapulars lying traversely behind each parietal and they bear a transverse commissure of the lateral line. The medial extrascapular is sometimes called as post-parietal while the lateral extra-scapular is known as tabular. The tabular in *O. punctatus* actually occupies a lateral position behind the parietal and is also traversed by a transverse branch of the lateral line. The other two bones supra-temporal and post-frontal have also been given other names in different fishes. As a matter of fact these bones have double origin. They are formed in the cartilage and then dermal bones overlap them and finally the two bones become fused. The cartilage bones so formed have been called by de Beer (1937) as pterotic (autopterotic) and sphenotic (autosphenotic) and their counterparts in dermal bones are called the supra-temporal (dermopterotic) and post-frontal (dermosphenotic).

As regards frontals Kindred (1919) has also found two centres of ossification in *Amiurus* and therefore a case similar to *O. punctatus*.

Vomer arises from a single centre of ossification in *O. punctatus*. Gaupp (1905) in *Salmo* and Bamford (1949) in *Galeichthys* have shown paired origin of vomer.

As is well known Huxley (1876) subdivided the types of suspension of the jaws into three categories viz. amphistylic, hyostylic and autostylic. The classification has been revised by Gregory (1904) who distinguishes six types and later by de Beer (1937) who distinguishes nine types. In these classifications only the primitive jaws i. e. the pterygoquadrate and Meckel's cartilage, the hyomandibular cartilage and their direct derivatives are involved. Extension of meaning to include the nature of the dermal jaws has been the chief conflicting factor. In autostylic jaw suspension where the hyomandibular is reduced, the pterogoquadrate articulates with the skull by its own processes which to a maximum can be an otic process, a basal process, a process ascendens and an ethmo-palatine process, all of which are never present at a time. In the primitive Teleostomes where hyomandibular is well developed the pterygoquadrate also articulates with the cranium by a basal process, which lies infront of the palatine branch of the facial nerve. This has been referred to as the amphistylic type of jaw articulation. It was present in Crossopterygii, Coelacanthini, primitive Chondrostei and Amioidei (Goodrich 1930). Among the living forms it exists in *Lepidosteus* as described by Aumonier (1941). In Teleostei the basal process is recognised by Swinnerton (1902) and Allis (1903) and is considered to be represented by the metapterygoid process. In *O. striates* Bhimachar (1932) describes the metapterygoid process articulating with the frontal but does not refer about the amphistylic type of jaw articulation in this fish. *Symbranchus* and *Zoarces* possess a metapterygoid process which articulates with the side wall of the skull apart from the hyomandibular articulation and these types have been referred by Berg (1947) as amphistylic articulations.

SUMMARY

Ossification of the skull bones of *O. punctatus* is described and an account has been given of the bones in relation to jaw articulation. For the study of ossification five stages 3 mm, 5 mm, 8 mm, 15 mm and 30 mm were selected. Special points of interest are as follows:

1. Dentary and opercular ossifications are the first to appear.

2. Premaxillae, vomer and palatines when they first appear are without teeth which appear much later.

3. Lacrymal of the adult is lacrymal plus the antorbital of the embryo.

4. A tabular is present.

5. Vomer arises by a single ossification.

6. Frontal of the adult arises by two ossifications, supra-orbital and frontal which become subsequently fused.

7. Pterotic, sphenotic, supra-occipital, metapterygoid, articular and angular are formed from the fusion of both the cartilage and the dermal elements.

8. A urohyal is present.

9. The jaw articulation in the embryo is of the methyostylic type but in the adult metapterygoid bone also articulates with the skull and thus an amphistylic type of jaw suspension is formed.

ACKNOWLEDGMENTS

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STUDIES IN THE HYDROPHYTES OF GORAKHPUR: OBSERVATIONS ON THE ANATOMICO-PHYSIOLOGICAL CHARACTERS OF JUSSIEUA REPENS. LINN.

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INTRODUCTION

The study of physiological anatomy is important because it throws light on the function of different tissues as modified by environmental conditions. In this connection it may be mentioned that Moss (1936) found in the case of the common "fire wood" *Epilobium angustifolium* (Onagraceae), "that interxylary periderm affords the plant excellent protection against desiccation, pathogenic organisms and possibly other deleterious effects associated with the dying down of annual shoots, and consequently make for continuance and for efficient functioning of perennating structures".

THE PLANT AND HIS HABITAT

Onagraceae to which *Jussieua repens* belongs has been designated as an aquatic family, consisting of a few genera. Two species of *Jussieua* are found at Gorakhpur as aquatic or marshy plants, viz., *J. repens* and *J. suffruticosa*, the former being more common than the latter.

Pattnaik and Patnaik (1956) have classified *J. repens* as a floating plant. It is a herb with creeping or floating stem, depending on environmental conditions, which determine its morphological and physiological characters. For example, the stem when floating or in a swampy habitat, develops spongy breathing vesicles from below the insertions of leaves, (Fig. 1), otherwise these structures are completely missing from the plant. It also grows very well as a land plant, (Fig. 2).

A comparative statement of morphological changes brought about by variations in environmental conditions is given below:

Plants floating on water	*Plants growing on land*
1. Plants show white spongy vesicles, the breathing roots, from below the insertion of the leaves.	1. No trace of such vesicles.
2. Stems are smooth without any trichomal growth.	2. Stems and leaves show a profuse development of uniseriate trichomes. The stem grows like a runner.
3. Internodes are longer and the stem thicker and softer.	3. Internodes, are shorter, stem thinner and harder.
4. Leaves are larger and inserted at longer intervals.	4. Leaves are smaller and many seem to be coming out from a place due to shortening of internodes.
5. Long thin fibrous roots develop below each node.	5. No such roots can be observed. They are somewhat spongy.

Fig. 1. Floating form of the plant. (Natural Size).

Fig. 2. Land form of the plant. (Natural Size).

From the comparative statement given above it may be infered that the morphological make up of the plant is modified to a very large extent because of changes in the habitat and hence it is likely that the physiology of the tissues may be somewhat modified.

MATERIAL AND METHOD

Jussieua repens was collected first of all by the author in January, 1957, with breathing roots from the swamps of a rice field near Ram Garh Tal (Gorakhpur) and again in February, 1957 from Narhi Tal (Gorakhpur) where the plants were found growing in the two diverse habitats viz., water and land. It was also collected from Asuran Pokhra (Gorakhpur) in April, 1957, when it was both in flowering and fruiting stages. Both aquatic and land forms were collected and fixed in Formaline-Acetic-Alcohol. The anatomical studies for this paper are based mostly on the free hand sectioning to facilitate the comparative study of the two forms without much delay. Microtome preperations do not give satisfactory results for hydrophytic plants and take much longer time.

DESCRIPTION

1. *Epidermis.* It consists of a single layer of thin walled convex cells, without any cuticle in aquatic forms. Fewer stomata and hairs are present in aquatic forms, but both these increase in land forms. Hairs are uniseriate. Chloroplast and starch grains are seen in epidermis, (Fig. 3). Stomata do not resemble cruciferous type but are mostly surrounded by four subsidiary cells, (Figs. 8-9).

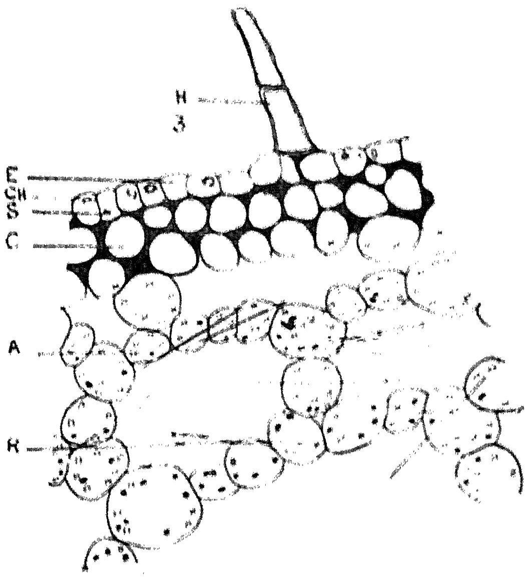

Fig. 3. Part of the T. S. of stem of the floating form, showing the epidermis with chloroplasts and starch grains, the collenchymatous outer cortex, and the aerenchymatous inner cortex, with chloroplasts and starch grains, and also raphides. × 150.

2. *Cortex.* The outer cortex consists of 2-3 layers of feebly developed collenchyma in portions which are submerged, and more developed in portions outside water. It possesses both chloroplast and starch grains. The inner part of the cortex is made up of aerenchyma, with large air-spaces. The cells here have starch grains, which are smaller in size and less packed up than those of pith and xylem elements. Raphides are abundant in this region, (Fig. 3), which are

not accompanied by clustered crystals (Metcalfe and Chalk, 1950). The innermost part of the cortex consists of 1-2 layers of parenchyma abutting against the endodermis and possesing more starch grains than outer cells.

The endodermis is distinct as a wavy layer ; cells contain comparatively less starch grains, (Fig. 4).

3. *Pericycle*. The nature of the 'pericycle' and pericycle fibres are controversial, (Eames and MacDaniels, 1947, Metcalfe and Chalk, 1950, Esau, 1953). So the term pericycle here used is adopted more for its positional rather than the anatomical value. The cells below endodermis consist of isolated fibre cells in groups of 2-4 ; and such cells even occur singly. Thus there are radially alternating zones of thin walled parenchyma cells and thick walled sclerenchyma fibres, (Fig. 4).

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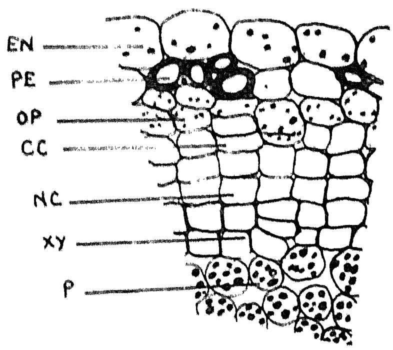

Fig. 4. Part of the T. S. of stem, showing the endodermis with few starch grains, the pericycle which include radially alternating zones of thin walled parenchymatous cells and thick walled sclerenchymatous fibres, followed by phloem cork cambium and normal cambium, and lignified tissue of xylem elements, near the starch filled parenchymatous cells. × 150.

4. *Cork*. The cork cambium arises below the 'pericycle' or cells of the phloem in early stages to give rise to cork. Cambium cells just touching the phloem are very distinct and are thin walled and rectangular in shape. Cork cells are thin walled and more or less circular in outline, (Fig. 4).

5. *Vascular System*. Phloem, cambium and xylem elements form continuous cylinders. Xylem is traversed by narrow rays.

Phloem cells contain starch. Internal phloem adjoins the xylem in 3-4 groups. Parenchyma cells, full of starch, are distinctly seen between the xylem and internal phloem, (Fig. 5). Additional phloem groups mostly arranged in two

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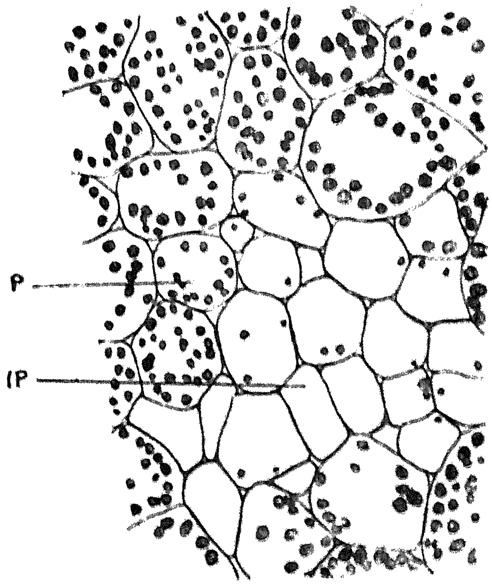

Fig. 5. Parenchymatous cells full of strach grains on both sides of the internal phloem. × 320.

isolated patches which sometimes fuse to form one, are also very prominent in the centarl part of the pith, (Fig. 6).

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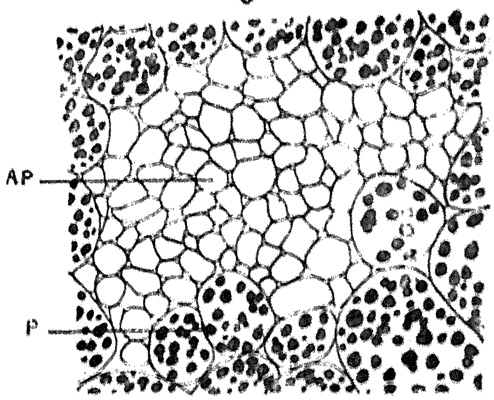

Fig. 6. A portion of central part of the pith, showing additional phloem group in an isolated patch × 150.

Xylem is very abnormal in the sense that it has very few vessels in comparison to other xylem elements, and are laden up with large starch grain, (Fig. 7). Xylem seems to have lost its normal function in this plant. Secondary growth is normal, Rays also occur in the region of secondary xylem.

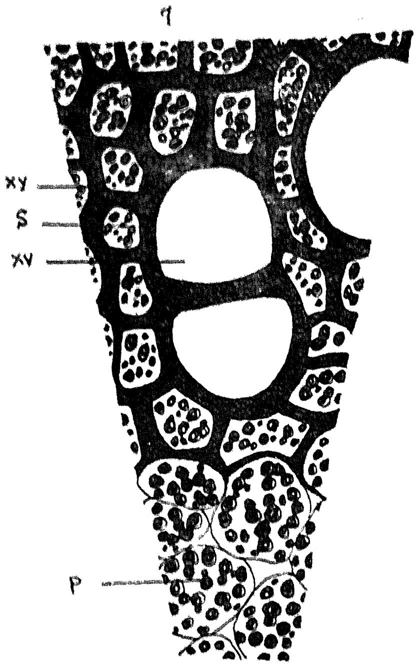

Fig. 7. A portion of xylem showing one half and two complete vessels and other elements which are laden up with starch grains. A few parenchymatous cells having starch grains can also be seen towards the centre. × 320.

6. *Pith.* It consists of thin walled parenchymatous cells, which contain copious supply of starch grains. Starch grains increase in size and number per parenchymatous cell from the periphery towards centre.

7. *Breathing Roots.* Schenck (1889) has studied the breathing roots in *Jussieua.* They have a massive arenchyma made up of numerous concentric layers representing the cortex. The epidermis and hypodermis are lost at early stages of development and so these roots have a free communication directly with the outside atmosphere.

8. *Ordinary Roots.* Normal roots have epiblema and a large portion of parenchyma cells constituting the cortex without any distinct air spaces. The roots have tetrarch to pentarch stele, which is very much reduced. Contrary to the condition found in the stem, there are no starch grains in any of the tissues of the roots.

9. *Leaf.* Hairs are present on both the surfaces of leaf. Air spaces are developed in the lower side of the mild rib region. The parenchyma cells have chloroplats only in the two wings, those occuring in the two sides of the lamina becoming more numerous till the appearance of spongy tissue. A single layer of palisade cells is found on the upper side. Stomata are more on the upper than on the lower surface, (Figs. 8-9), each stoma is surrounded by more than three subsidiary cells.

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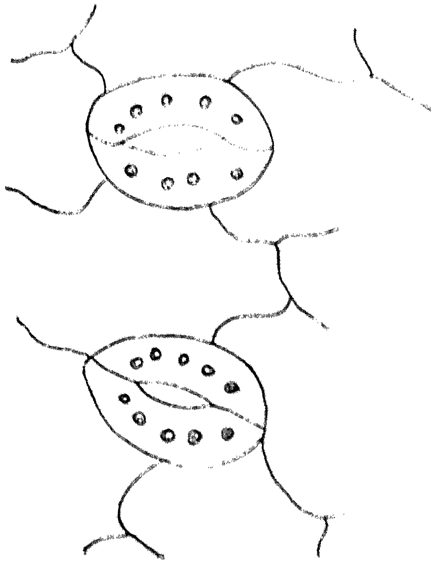

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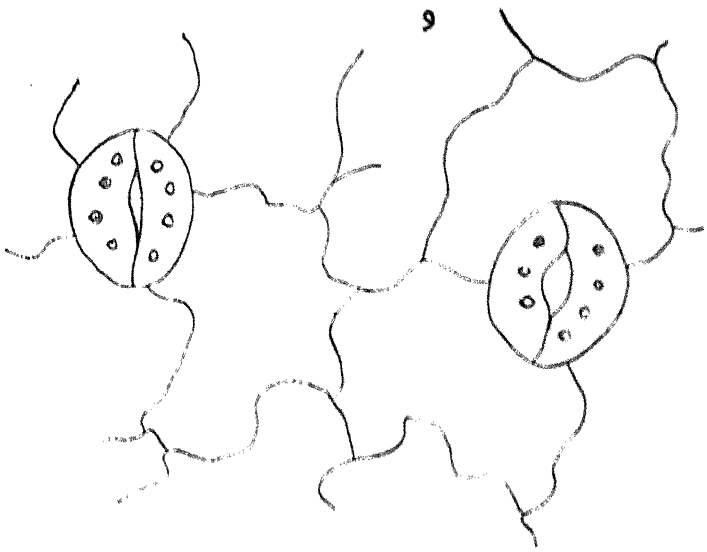

Figs. 8 & 9. A part of the upper and lower epidermis showing stomata. × 600.

The mid rib has a single arc-shaped vascular strand with no lateral acessory strands. The endodermis with starch grains, is distinct on the lower side only. A

few xylem vessels are present interior to phloem elements. The vascular strand here is not bicollateral, (Fig. 10).

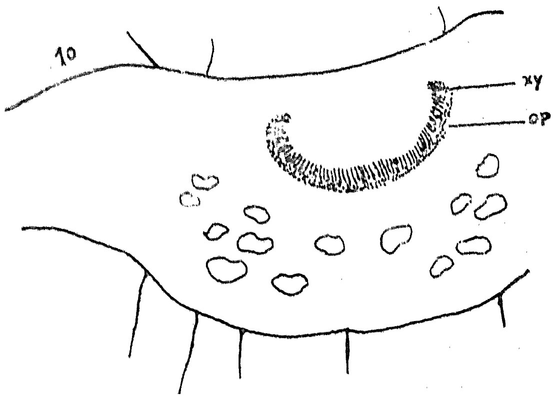

Fig. 10. An outline diagram of T. S. of leaf showing the midrib with a single arc-shaped vascular strand, which is not bicollateral. × 32.

ANATOMICO-PHYSIOLOGICAL ASPECT

Jussieua repens germinates and grows in water as an aquatic, but as environmental conditions change, it takes to land habit. With this change in the habitat a number of anatomical transformations occur to equip the plant to carry on the physiological functions in its new set-up. The presence of breathing spongy roots seem to be an aid in supporting the submerged parts of the plants as also for respiratory activity and storage of gases. This structure can hardly be a floating device, as the plants float well, even if they are removed, (Goebel, 1891-1893). These are absent in plants growing on land.

A reduction of protective, supportive, and conductive tissues take place as long as the plant remains in water, with the consequent increase of the air cavities needed for the bouyancy and storage of gases. The anatomical variations are almost uniform in the hydrophytes on account of the uniformity of the aquatic environments in which the plant finds itself. An increase in the tissues mentioned above takes place consequent upon its adoption of terresterial life.

DISCUSSION

As is evident from the foregoing account, *Jussieua repens* has the capacity to live as an aquatic as well as a land plant with the development of morphological variations required for terrestrial life, the physiology of tissues changing with changes in the anatomy of the plant organs. The following characteristic correlation of anatomy and physiology in the case of this plant is noteworthy :

(*i*) The absence of cuticle and the presence of fewer hairs in the submerged portions of the stem, together with the development of chloroplast in the epidermis, would facilitate the photosynthetic activity.

(*ii*) The feeble development of collenchyma in submerged parts is indicative of hydrophytic nature of the plant; its comparative greater development in plants growing on land may be correlated with the necessity of greater support required for the terrestrial habitat.

(*iii*) The production of large air spaces in the cortex for the bouyancy and aeration would seem to be necessary to an aquatic set up.

(*iv*) The production of breathing roots is another concomitant of aquatic surrounding; their absence in terrestrial environment is as should be expected.

(*v*) The reduction in the thickening of the pericyclic fibres is characteristic of aquatic environment because support is not needed in such an environment.

(*vi*) The reduction in the thickening and amount of xylem elements are also correlated with aquatic environment. The primary function of the xylem and its constituent cells is to afford facility for conduction and support which become rudiment in aquatic surrounding. The main function of this tissue is modified to that of storage. The functional modification of the xylem elements is an acquired character. When the plant takes to land life, the normal function of the xylem is restored and therefore in such plants starch is not found in the elements composing this tissue. The lower region of plant which remain in water, store starch, as they do not function in conduction. This fact which is so distinct a characteristic of this aquatic plant has not been reported by Mirashi who worked out a number of hydrophytes. (Mirashi, 1954-58).

(*vii*) The presence of abundant starch grains in the pith cells indicate that it functions mainly as a storage tissue.

With the consequent drying of the habitat the changes that are brought about in the n orphology and anatomy of the plant modify its physiological set up.

SUMMARY

The anatomico-physiological characters of *Jussieua repens* have been studied in this paper. The plant grows in water as an aquatic, but as environmental conditions change, it takes to a land habit. With this change in the habitat a number of anatomical transformations occur to equip the plant to carry on the physiological functions. A number of changes in the physiology of the tissues occur such as the function of xylem elements as storage organ, which is primarily a conductive tissue, is quite abnormal. Additional phloem groups in isolated patches in the central part of the pith have been recorded.

With the consequent wetting or drying of the habitat, the anatomico-physiological aspect of the plant is changed, to equip it to its best in that particular environmental condition.

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ABBREVIATIONS USED

A—Aerenchyma;	AP—Additional Phloem;	BR—Breathing Roots;
C—Collenchyma;	CC—Cork Cambium;	CH—Chloroplasts;
E—Epidermis;	EN—Endodermis;	H—Hair;
IP—Internal Phloem;	NC—Normal Cambium;	OH—Outer Phloem;
P—Parenchyma;	PE—Pericycle;	R—Raphides;
S—Starch Grains;	XV—Xylem Vessels;	X—Xylem Elements.

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TOXICITY OF ORGANIC INSECTICIDES TO CERTAIN FISHES

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The present study was undertaken to determine the minimum lethal concentration of different insecticides to certain fishes and at the same time to find out whether wide spread use of these insecticides may not cause destruction of the acquatic life in the ponds etc. With this object in view toxicological tests with four organic insecticides viz., DDT, BHC, Lindane and Dieldrin were carried out on a few fishes. In all these bio-assay tests fishes were fully fed in order to eliminate the starvation factor. These tests along with controls were conducted at room temperature where the test fishes had been previously acclimatized. Artificial oxygenation is not normally required and absorption of atmospheric oxygen by the exposed water surface was usually sufficient for the fish requirement during the test period. On the controls no mortality occurred among the fishes.

The fishes used in this toxicity study were

(1) *Trichogaster chuna*

(2) *Clarias batrachus*

(1) Effect of DDT :

(*a*) *Lethal dose for Trichogaster chuna*—The test was conducted in a small trough containing two liters of tap water and one *Trichogaster chuna* weighing 1 gm and measuring 2·5 cms was kept in it. Then 1 cc of 25% DDT emulsion was sprayed in the container. The fish died in two hours. Lethal effects were noted at 500 p. p. m. dosage. Some very peculiar symptoms were noted when the fish came in contact with DDT. As soon as the fish came in contact with DDT, it became very much excited and frequently came to the top of the container for gulping fresh quantity of air. At the point of death it began to float in an upside down position. Ultimately the rate of respiration became slow and the equilibrium was lost and the fish died.

In another experiment in a small battery jar four liters of tap water was taken and one *Trichogaster chuna* weighing 1 gm and measuring 3 cms was kept in it. Then 4 cc of 25% DDT emulsion was sprayed. The fish died in 1 hour and 15 minutes. 1000 p. p. m. was lethal to it. Its behaviour was similar as in previous case.

(*b*) *Lethal dose for Clarias batrachus*—In a trough 5 liters of water was taken and one *Clarias batrachus* weighing 25 gms and measuring 14·5 cms was kept in it. Then 5 cc of 25% DDT emulsion was sprayed. The fish died in two hours. 1000 p. p. m. was lethal to it.

The fish when came in contact with DDT showed high excitability followed by sudden convulsive movements, causing jerky and violent movements. Later the fish started losing the balance and laid on its sides. Ultimately the equilibrium was lost and the fish died.

In another experiment in 5 liters of water two specimens of *clarias batrachus* weighing 16 gms and 20 gms and measuring 16 cms and 18 cms respectively were kept. Then 5 cc of 25% DDT emulsion was sprayed. Both the fishes died in two hours. 1000 p. p. m. was toxic to it. Symptoms were identical as in previous case.

(2) Effect of Lindane :

(a) Lethal dose for Trichogaster chuna—In 4 liters of water one *Trichogaster chuna* weighing 1 gm and measuring 3·8 cms was kept. Then 6 cc of commercial Lindane was sprayed. In 45 minutes the fish was dead. 1500 p. p. m. was toxic to it. As soon as Lindane was sprayed the fish got much excited and frequently came to the top of the container for gulping fresh air followed by convulsions. It lost the equilibrium finally and died.

In another experiment in 3 liters of water one *Trichogaster chuna* weighing 2 gms and measuring 4·6 cms was kept. Then 5 cc of Commercial Lindane was sprayed. The fish died in 50 minutes. 1666·5 p. p. m. was lethal to it. Symptoms were similar as in previous case.

(b) Lethal dose for clarias batrachus—In 5 liters of water one *Clarias batrachus* weighing 27 gms and measuring 16·5 cms was kept. Then 15 cc of Commercial Lindane was sprayed. In 30 minutes the fish was dead. Lethal effects were noted at 3000 p. p. m. The fish showed convulsions and this was followed by quiescent period with loss of balance.

(3) Effect of Dieldrin

(a) Lethal dose for Clarias batrachus—In 5 liters of water two *Clarias batrachus* of different weight and size were kept. Bigger one was weighing 30 gms. and measuring 17 cms. and smaller one was weighing 22 gms. and measuring 14·5 cms. Then 25 cc of Technical dieldrin was sprayed. The smaller fish died in 4 hours and 15 minutes and the larger fish died in 5 hours. 5000 p. p. m. was lethal to it. As soon as Dieldrin was sprayed the fish started showing convulsions. Late the equilibrium was lost and ultimately the fish died.

(b) Lethal dose for Trichogaster chuna—The tests were carried out in small jars with 3 liters of water. In this jar one *Trichogaster chuna* weighing 1 gm and measuring 4·2 cms was kept in it. Then 6 cc of Technial dieldrin was sprayed. The fish died in 4 hours and 30 Minutes. 2000 p.p m. was toxic to it The fish developed certain symptoms after the spraying of Dieldrin. The fish frequently came to the top of the container for gulping fresh air. For a while the fish remain suspended in vertical position in the container and then after few movements it regained its original form. Ultimately the balance was lost and the fish died.

In another experiment in 3 liters of water one *Trichogaster chuna* weighing 1 gm and measuring 3·7 cms was kept. Then 12 cc of Technical Dieldrin was sprayed. The fish died in 3 hours. 4000 p.p.m. was lethal to it.

(4) Effect of BHC

(a) Lethal dose for Trichogaster chuna—The tests were performed in small aquaria with 3 liters of water. In this small aquaria one *Trichogaster chuna* weighing 1 gm and measuring 4 cm was kept. Then 12 cc of BHC (10%) was sprayed. The fish died in 4 hours. 4000 p.p.m. was toxic to it.

In another experiment in 3 liters of water one *Trichogaster chuna* weighing 5 gms and measuring 3 cms was kept. Then 12 cc of BHC (5%) was sprayed. The fish died in 5 hours. 4000 p. p. m. was lethal to it. The fish showed convulsion. Later laid on its side and lost balance and died.

(*b*) *Lethal dose for Clarias batrachus*—The experiment was performed in small jars. In 6 liters of water one *Clarias batrachus* weighing 23 gms and measuring 15·6 cms was kept. Then 24 cc of BHC (20%) was sprayed. The fish died in 45 minutes. 4000 p. p. m. was toxic to it. Symptoms were identical as in previous case.

SUMMARY

(1) Toxicological tests were conducted with four chlorinated hydrocarbon insecticides to determine their comparative toxicity to these fishes.

(2) At higher concentration (5000 p. p. m.) the first visible evidence of the effect occurred after 30 to 60 minutes of exposure while at lower concentration (200 p. p. m.) a much larger time was required.

(3) Various sizes of fishes were exposed to different formulation of DDT, BHC, Lindane and Dieldrin, so that the difference between age and species susceptibility could be determined.

(4) The affected fishes showed few characteristic symptoms—the fishes showed a brief period of high excitability followed by convulsive movements, causing jerky and violent movements. Very short quiescent period followed with loss of equilibrium.

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